Civil Engineering

SMART Scan

AE, JE, State PSC, ESE, PSU's & Other Competitive Exams

SSC-JE (Pre & Mains) | RRB-JE | UPSSSC-JE | UPPSC-AE :

• NHPC-JE • UKPSC AE • BPSC AE • CGPSC AE • MPPSC AE • RPSC AE • DMRC JE • LMRC JE • JMRC JE • BMRC JE • DSSSB JE/AE • SJVN JE • UKSSSC JE • RSMSSB JE • HPSSC JE • MPPEB SUB ENGINEER • DDA-AE/JE • HSSC JE • JSSC JE • BSSC JE • DRDO JE • ISRO • CGPEB SUB ENGINEER • UPPCL AE/JE • UPRVUNL AE/JE • JVUNL JE • SAIL JE • GAIL JE •BHEL JE • NTPC JE • DFCCIL • COAL INDIA LTD. JE • WBPSC AE • TAMILNADU TRB • TNPSC AE • J&K PSC AE • SIKKIM PSC AE • OPSC AE • MPSC AE • GUJARAT PSC AE • PTCUL

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Index

CIVIL & STRUCTURAL ENGINEERING

The Examination will be conducted in two stages:

A. Paper-I (Pre) (200 marks)

B. Paper-II (Mains) (300 marks)

Total Written Test (500 marks)

Written Test :

Paper	Mode of Examination	Subject	Number of Questions/Max. Marks	Duration & Timing
Paper-I Objective type	Computer Based Examination	(i) General Intelligence & Reasoning (ii) General Awareness (iii) General Engineering (CIVIL & Structural)	50/50 50/50 100/100	2 Hours
Paper-II Objective Type	Computer Based Examination	General Engineering (CIVIL & Structural)	100/300	2 Hours

There will be **negative marking equal to one-third (1/3) of the marks** allotted to the question for each wrong answer in Paper-I & Paper-II.

SSC JE Syllabus

- **Indicative Syllabus:** The standard of the questions in Engineering subjects will be approximately of the level of Diploma in Engineering (Civil/Mechanical) from a recognized Institute, Board or University recognized by All India Board of Technical Education. All the questions will be set in SI units. The details of the syllabus are given below.

Paper-I (Prelims)

- ***General Intelligence & Reasoning:*** The Syllabus for General Intelligence would include questions of both verbal and non-verbal type. The test may include questions on analogies, similarities, differences, space visualization, problem solving, analysis, judgment, decision making, visual memory, discrimination, observation, relationship concepts, arithmetical reasoning, verbal and figure classification, arithmetical number series etc. The test will also include questions designed to test the candidate's abilities to deal with abstract ideas and symbols and their relationships, arithmetical computations and other analytical functions.
- ***General Awareness:*** Questions will be aimed at testing the candidate's general awareness of the environment around him/her and its application to society. Questions will also be designed to test knowledge of current

events and of such matters of everyday observations and experience in their scientific aspect as may be expected of any educated person. The test will also include questions relating to India and its neighbouring countries especially pertaining to History, Culture, Geography, Economic Scenario, General Polity and Scientific Research, etc. These questions will be such that they do not require a special study of any discipline.

- **General Engineering (Civil and Structural)**
- **Civil Engineering :** Building Materials, Estimating, Costing and Valuation, Surveying, Soil Mechanics, Hydraulics, Irrigation Engineering, Transportation Engineering, Environmental Engineering.
- **Structural Engineering :** Theory of Structures, Concrete Technology, RCC Design, Steel Design.

Paper-II (Mains)

Civil & Structural Engineering

- **Building Materials :** Physical and Chemical properties, classification, standard tests, uses and manufacture/quarrying of materials e.g. buildings stones, silicate based materials, cement (Portland), asbestos products, timber and wood based products, laminates, bituminous materials, paints, varnishes.
- **Estimating, Costing and Valuation :** Estimate, glossary of technical terms, analysis of rates, methods and unit of measurement, Items of work – earthwork, Brick work (Modular & Traditional bricks), RCC work, Shuttering, Timber work, Painting, Flooring, Plastering. Boundary wall, Brick building, Water Tank, Septic tank, Bar bending schedule, Centre line method, Mid-section formula, Trapezoidal formula, simpson's rule, Cost estimate of Septic tank, flexible pavements, Tube well, isolates and combined footings, Steel Truss, Piles and pile-caps. Valuation – Value and cost, scrap value, salvage value, assessed value, sinking fund, depreciation and obsolescence, methods of valuation.
- **Surveying :** Principles of surveying, measurement of distance, chain surveying, working of prismatic compass, compass traversing, bearings, local attraction, plane table surveying, theodolite traversing, adjustment of theodolite, Levelling, Definition of terms used in levelling, contouring, curvature and refraction corrections, temporary and permanent adjustments of dumpy level, methods of contouring, uses of contour map, tachometric survey, curve setting, earth work calculation, advanced surveying equipment.
- **Soil Mechanics :** Origin of soil, phase diagram, Definitions-void ratio, porosity, degree of saturation, water content, specific gravity of soil grains, unit weights, density index and interrelationship of different parameters, Grain size distribution curves and their uses. Index properties of soils, Atterberg's limits, ISI soil classification and plasticity chart. permeability of soil, coefficient of permeability, determination of coefficient of permeability, Unconfined and confined aquifers, effective stress, quick sand, consolidation of soils, Principles of consolidation, degree of consolidation, pre-consolidation pressure, normally consolidated soil, e-log p curve, computation of ultimate settlement. Shear strength of soils, direct shear test, Vane shear test, Triaxial test. Soil compaction, Laboratory compaction test, Maximum dry density and optimum moisture content, earth pressure theories, active and passive earth pressures, Bearing capacity of soils, plate load test, standard penetration test.
- **Hydraulics :** Fluid properties, hydrostatics, measurements of flow, Bernoulli's theorem and its application, flow through pipes, flow in open channels, weirs, flumes, spillways, pumps and turbines.

- **Irrigation Engineering :** Definition, necessity, benefits, 2II effects of irrigation, types and methods of irrigation, Hydrology – Measurement of rainfall, run off coefficient, rain gauge, losses from precipitation – evaporation, infiltration, etc. Water requirement of crops, duty, delta and base period, Kharif and Rabi Crops, Command area, Time factor, Crop ratio, Overlap allowance, Irrigation efficiencies. Different type of canal irrigation, loss of water in canals. Canal lining – types and advantages. Shallow and deep wells, yield from a well. Weir and barrage, Failure of weirs and permeable foundation, Slit and Scour, Kennedy's theory of critical velocity. Lacey's theory of uniform flow. Definition of flood, causes and effects, methods of flood control, water logging, preventive measure. Land reclamation, Characteristics of affecting fertility of soils, purposes, methods, description of land and reclamation processes. Major irrigation projects in India.
- **Transportation Engineering :** Highway Engineering – cross sectional elements, geometric design, types of pavements, pavements materials – aggregates and bitumen, different tests, Design of flexible and rigid pavements – Water Bound Macadam (WBM) and Wet Mix Macadam (WMM), Gravel Road, Bituminous construction, Rigid pavement joint, pavement maintenance, Highway drainage, Railway Engineering – components of permanent way – sleepers, ballast, fixtures and fastening, track geometry, points and crossings, track junction, stations and yards. Traffic Engineering – Different traffic survey, speed- flow-density and their interrelationships, intersections and interchanges, traffic signals, traffic operation, traffic signs and markings, road safety.
- **Environmental Engineering :** Quality of water, source of water supply, purification of water, distribution of water, need of sanitation, sewerage systems, circular sewer, oval sewer, sewer appurtenances, sewage treatments. Surface water drainage. Solid waste management – types, effects, engineered management system, Air pollution – pollutants, causes, effects, control. Noise pollution – cause, health effects, control.

Structural Engineering

- **Theory of structures :** Elasticity constants, types of beams – determinate and indeterminate, bending moment and shear force diagrams of simply supported, cantilever and over hanging beams, Moment of area and moment of inertia for rectangular & circular sections, bending moment and shear stress for tee, channel and compound sections, chimneys, dams and retaining walls, eccentric loads, slope deflection of simply supported and cantilever beams, critical load and columns, Torsion of circular section.
- **Concrete Technology :** Properties, Advantages and uses of concrete, cement aggregates, importance of water quality, water cement ratio, workability, mix design, storage, batching, mixing, placement, compaction, finishing and curing of concrete, quality control of concrete, hot weather and cold weather concreting, repair and maintenance of concrete structures.
- **RCC Design :** RCC beams-flexural strength, shear strength, bond strength, design of singly reinforced and double reinforced beams, cantilever beams. T-beams, lintels. One way and two way slabs, isolated footings. Reinforced brick works, columns, staircases, retaining wall, water tanks (RCC design questions may be based on both Limit State and Working Stress methods).
- **Steel Design :** Steel design and construction of steel columns, beams roof trusses plate girders.

UPPSC

Uttar Pradesh Public Service Commission

Government of UP, Prayagraj

Combined State Engineering Services

(General Recruitment/Special Recruitment)

Examination Pattern and Syllabus

The following two objective type papers will be for the Combined State Engineering Services Examination.

PAPER-I

Subject	No. of Questions	Marks	Total Marks	Time
General Hindi	25 (Each question of 3 marks)	75	375	2.30 Hours
Main Subject (Civil Engg.-I)	100 (Each question of 3 marks)	300		

PAPER-II

Subject	No. of Questions	Marks	Total Marks	Time
General Studies	25 (Each question of 3 marks)	75	375	2.30 Hours
Main Subject (Civil Engg.-II)	100 (Each question of 3 marks)	300		

Personal Examination (Interview) – 100 Marks

Total – 375 + 375 + 100 = 850 Marks

SYLLABUS

General Hindi – Hindi syllabus will be made in such a way that the candidates under standing of Hindi language and efficient use of words can be checked. Its level will be of high school.

General Studies – The question paper of General Studies will include information focusing on current events and their scientific aspects of such things which come in everyday experience and which can be expected from an educated person. The question paper will also included such questions in the history, politics and geography of India, to which candidates will be able to answer without special study.

CIVIL ENGINEERING PAPER – 1

PART – A

ENGINEERING MECHANICS, STRENGTH OF MATERIALS AND STRUCTURAL ANALYSIS

Units and Dimensions, SI units, vectors, concept of force, Concept of particle and rigid body Concurrent, Non-Concurrent and parallel forces in a plane, moment of force and varignon`s theorem free body diagram, conditions of equilibrium Principle of virtual work, equivalent force system.

First and second Moment of area, Mass moment of inertia, Static Friction, inclined plane and bearings, kinematics and kinetics, kinematics in Cartesion and Polar Coordinates, motion under uniform and non-uniform acceleration, motion under gravity, Kinetics of particle: Momentum and Energy principles, D` Alembert`s principle, Collision of elastic bodies, rotation of rigid, bodies, simple harmonic motion.

STRENGTH OF MATERIALS

Simple Stress and Strain, Elastic constants, axially loaded compression members, Shear force and bending moment, theory of simple bending, bending stress, Shear Stress, Beams of uniform strength, Leaf Spring, close coiled helical springs, Strain Energy in direct stress, bending & shear. Deflection of beams; Macaulay's method, Mohr's Moment area

method, Conjugate beam method, unit load method, Torsion of shafts, Transmission of power, Elastic stability of columns, Euler's Rankin's and Secant formulae. Principal stresses and strains in two dimensions, Mohr's Circle, Theories of Elastic Failure, Thin and Thick cylinder, Stresses due to internal and external pressure- Lame's equations.

STRUCTURAL ANALYSIS

Castiglianio's theorems I and II, Unit load method of consistent deformation applied to beams and pin jointed trusses. Slope-deflection, moment distribution, Kani's method of analysis and column Analogy method applied to indeterminate beams and rigid frames. Rolling loads and influence lines: Influence lines for reactions of beam, shear force and bending moment at a section of beam criteria for maximum shear force and bending moment in beams traversed by a system of moving loads, influence lines for simply supported plane pin jointed trusses, Arches : Three hinged, two hinged and fixed arches, rib shortening and temperature effects, influence lines in arches, Matrix methods of analysis: Force method and displacement method of analysis of indeterminate beams and rigid frames. Plastic Analysis of beams and frames: Theory of plastic bending, plastic analysis, statical method, Mechanism method. Unsymmetrical bending: Moment of inertia, product of inertia, position of neutral axis and principal axis, calculation of bending stresses.

PART – B

DESIGN OF STRUCTURES : STEEL, CONCRETE AND MASONRY STRUCTURES.

STRUCTURAL STEEL DESIGN

Structural steel: Factors of safety and load factors, riveted, bolted and welded joints and its connections, Design by working stress/limit state method of tension and compression member, beams of built up section, rivetted and welded plate girders, gantry girders, stancheons with battens and lacings, slab and gussetted column bases, Design of highway and railway bridges: Through and deck type plate girder, Warren girder, Pratt truss.

DESIGN OF CONCRETE AND MASONRY STRUCTURES

Reinforced Concrete: Working Stress and Limit State Method of design-Recommendations of B.I.S. codes, design of one way and two way slabs, stairs-case slabs, simple and continuous beams of rectangular, T and L sections, compression members under direct load with or without eccentricity, isolated and combined footings, Cantilever and counter-fort type retaining walls, Water tanks: Design requirements as per B.I.S. code for rectangular and circular tanks resting on ground, Pre-stressed concrete: Methods and systems of pre-stressing, anchorages, analysis and design of sections for flexure based on working stress, losses of pre-stress, Earth quake resistant design of building as per BIS code. Design of brick masonry as per I. S. Codes, Design of masonry
retaining walls.

PART – C

Building Materials, Construction Technology, Planning and Management Building Materials

Physical properties of construction materials with respect to their use: stones bricks, tiles, lime, glass, cement, mortars, Concrete, concept of mix design, Pozzolans, plasticizers, super plasticizers, Special concrete: roller compacted concrete, mass concrete, self compacting concrete, Ferro cement, Fiber reinforced concrete, high strength concrete, high performance concrete, Timber: properties, defects and common preservation treatments, Use and selection of materials for various uses e.g. Low cost housing, mass housing, high rise buildings.

Constructions Technology, Planning and Management

Masonry constructions using brick, stone, construction detailing and strength characteristics paints, varnishes, plastics, water proofing and damp proofing materials. Detailing of walls, floors, roofs, staircases, doors and windows. Plastering, pointing, flooring, roofing and construction features. Retrofitting of buildings, Principle of planning of building for residents and specific uses, National Building code provisions and uses. Basic principles of detailed and approximate estimating, specifications, rate analysis, principles of valuation of real property. Machinery for earthwork, concreting and their specific uses, factors affecting selection of construction equipments, operating cost of equipments. Construction activity, schedules, organizations, quality assurance principles. Basic principle of network CPM and PERT uses in construction monitoring, cost optimization and resource allocation. Basic principles of economic analysis and methods. Project profitability: Basis principles of financial planning, simple toll fixation criterions.

PART – D

GEO TECHNICAL ENGINEERING AND FOUNDATION ENGINEERING

Types of soils, phase relationships, consistency limits particles size distribution, classifications of soils, structure and clay mineralogy. Capillary water, effective stress and pore water pressure, Darcy's Law, factors affecting permeability, determination of permeability, permeability of stratified soil deposits. Seepage pressure, quick sand condition, compressibility and consolidation, Terzaghi's theory of one dimensional consolidation, consolidation test.

Compaction of soil, field control of compaction total stress and effective stress parameters, pore pressure parameters, shear strength of soils, Mohr Coulomb failure theory, shear tests.

Earth pressure at rest, active and passive pressures, Rankin's theory Coulomb's wedge theory, Graphical method of earth pressure on retaining wall, sheetpile walls, braced excavation, bearing capacity, Terzaghi and other important theories, net and gross bearing pressure.

Immediate and consolidation settlement, stability of slope, total stress and effective stress methods, conventional methods of slices, stability number.

Subsurface exploration, methods of boring, sampling, penetration tests, pressure meter tests, essential features of foundation, types of foundation, design criteria, choice of type of foundation, stress distribution in soils, Boussinessq's theory, Westergaard method, Newmark's chart, pressure bulb, contact, pressure, applicability of different bearing capacity theories, evaluation of bearing capacity from filed tests, allowable bearing capacity, settlement analysis, allowable settlement, proportioning of footing, isolated and combined footings, rafts, pile foundation, types of piles, plies capacity, static and dynamic analysis, design of pile groups, pile load test, settlement of piles lateral loads, foundation for bridges, Ground improvement techniques: sand drains, stone columns, grouting, soil stabilization geotextiles and geomembrane, Machine foundation: Natural frequency, design of machine foundations based on the recommendation of B.I.S. codes.

CIVIL ENGINEERING PAPER- II

Part – A

FLUID MECHANICS, OPEN CHANNEL FLOW, HYDRAULIC MACHINES AND HYDROPOWER ENGINEERING

Fluid Mechanics: Fluid properties and their roles in fluid motion, fluid statics including forces acting on plane and curved surfaces, Kinematics and Dynamics of Fluid flow:

Velocity and acceleration, stream lines, equation of continuity, irrotational and rotational flow, velocity potential and stream functions, flownet, methods of drawing flownet, source and sink, flow separation, free and forced vorties.

Flow control volume equation, continuity, momentum and energy equations, Navier-Strokes equation, Euler's equation of motion and application to fluid flow problems, pipe flow, plane, curved, stationary and moving vanes sluice gates, weirs, orifice meters and Venturi meters.

Dimensional Analysis and Similitude: Buckingham's Pi-theorem, dimensionless parameters, similitude theory, model laws, undistorted and distorted models.

Laminar Flow: Laminar flow between parallel, stationary and moving plates, flow through pipes.

Boundary Layer: Laminar and turbulent boundary layer on a flat plate, laminar sub-layer, smooth and rough boundaries, submerged flow, drag and lift and its applications.

Turbulent flow through pipes: Characteristics of turbulent flow, velocity distribution, pipe friction factor, hydraulic grade line and total energy line, siphons, expansion and contractions in pipes pipe networks, water hammer in pipes and surge tanks.

Open Channel Flow: Flow types, uniform and non uniform flows, momentum and energy correction factors, Specific energy and specific force, critical depth, resistance equations and roughness coefficient, rapidly varied flow, flow in transitions, Brink flow, Hydraulic jump and its applications, waves and surges, gradually varied flow, classification of surface profiles, control section, Integration of varied flow equation and their solution.

HYDRAULIC MACHINES AND HYDROPOWER

Centrifugal pumps-Types, characteristics, Net Positive Suction-head (NPSH), specific speed, Pumps in series and parallel.

Reciprocating pumps, Air vessels, Hydraulic ram, efficiency parameters, Rotary and positive displacement pumps, diaphragm and jet pumps.

Hydraulic turbines: types, classification, Choice of turbines, performance parameters, controls, characteristics, specific speed.

Principles of hydropower development: Types, layouts and component works, surge tanks, 'types and choice, Flow duration curves and dependable flow, Storage and pondage, Pumped storage plants, Special types of hydel plants.

Part – B

Hydrology and Water Resources Engineering

Hydrology: Hydrologic cycle, precipitation, evaporation, transpiration, infiltration, overland flow, hydrographs, flood frequency analysis, flood routing through a reservoir, channel flow routing- Muskingam method.

Ground Water flow: Specific yield, storage coefficient, coefficient of permeability, confined and unconfined aquifers, radial flow into a well under confined and unconfined conditions, Open wells and tube wells.

Ground and surface water recourses single and multipurpose projects, storage capacity of reservoirs, reservoir losses, reservoir sedimentation.

Water requirements of crops consumptive use, duty and delta, irrigation methods, Irrigation efficiencies.

Canals: Distribution systems for cannal irrigation, canal capacity, canal losses, alignment of main and distributory canals, Design of cannal by kennedy's and Lacey's thoeorie, Water logging and its prevention.

Diversion head works: Compenents, Principles and design of weirs on permeable and impermeable foundations, Khosla's theory, Bligh's creep theory Storage works.

Cross drainage works.

Types of dams, design principles of gravity and earth dams, stability analysis. Spillways: Spillway types energy dissipation.

River training: Objectives of river training, methods of river training and bank protection.

Part – C
Transportation Engineering

Highway Engineering: Principles of Highway alignments, classification and geometric design, elements and standards for roads.

Pavement: flexible and rigid pavements Design principles and methodology. Construction methods and materials for stabilized soil. WBM, Bituminous works and Cement Concrete roads.

Surface and sub-surface drainage arrangements for roads, culvert structures. Pavement distresses and strengthening by overlays.

Traffic surveys and their application in traffic planning, Typical design features for channelized, intersection, rotary etc., signal designs, standard traffic signs and markings.

Railway Engineering: Permanent way, ballast, sleeper, chair and faslenings, points, crossings, different types of turn outs, cross-over, setting out of points, Maintenance of track, super elevation, creep of rails ruling gradients, track resistance tractive effort, curve resistance, Station yards and station buildings, platform sidings, turn outs, Signals and interlocking, level crossings.

Air port Engineering: Layouts, Planning and design.

Part – D
Environmental Engineering

Water supply: Estimation of water demand, impurities in water and their significance, physical, chemical and bacteriological parameters and their analysis, waterborne diseases, standards for potable water.

Water collection & treatment: Intake structures, principles and design of sedimentation tank, coagulation cum flocculation units slow sand filter, rapid sand filter and pressure filter, theory & practices of chlorination, water softening, removal of taste and salinity, Sewerage Systems, Domestic and industrial wastes, storm, sewage, separate and combined systems, flow through sewers, design of sewers.

Waste water characterization: Solids, Dissolved oxygen (DO), BOD COD, TOC, and Nitrogen, Standards for disposal of effluent in normal water course and on to land.

Waste water treatment: Principles and design of wastewater Treatment units--,Screening, grit chamber, sedimentation tank activated sludge process, trickling filters, oxidation ditches, oxidation ponds, septic tank; Treatment and disposal of sludge; recycling of waste water.

Solid waste management: Classification, Collection and disposal of solid waste in rural and urban areas, Principles of solid waste management.

Environmental pollution: Air and water pollution and their control acts. Radioactive waste and their disposal Environmental impact assessment of Thermal power Plants, mines and river valley projects, Sustainable development.

Part – E
Survey and Engineering Geology

(a) **Surveying:** Common methods and instruments for distance and angle measurements in Civil Engineering works, their use in plane table traverse survey, levelling, triangulation, contouring and topographical maps. Survey layouts for culverts canal, bridge, roads, railway alignment and buildings.

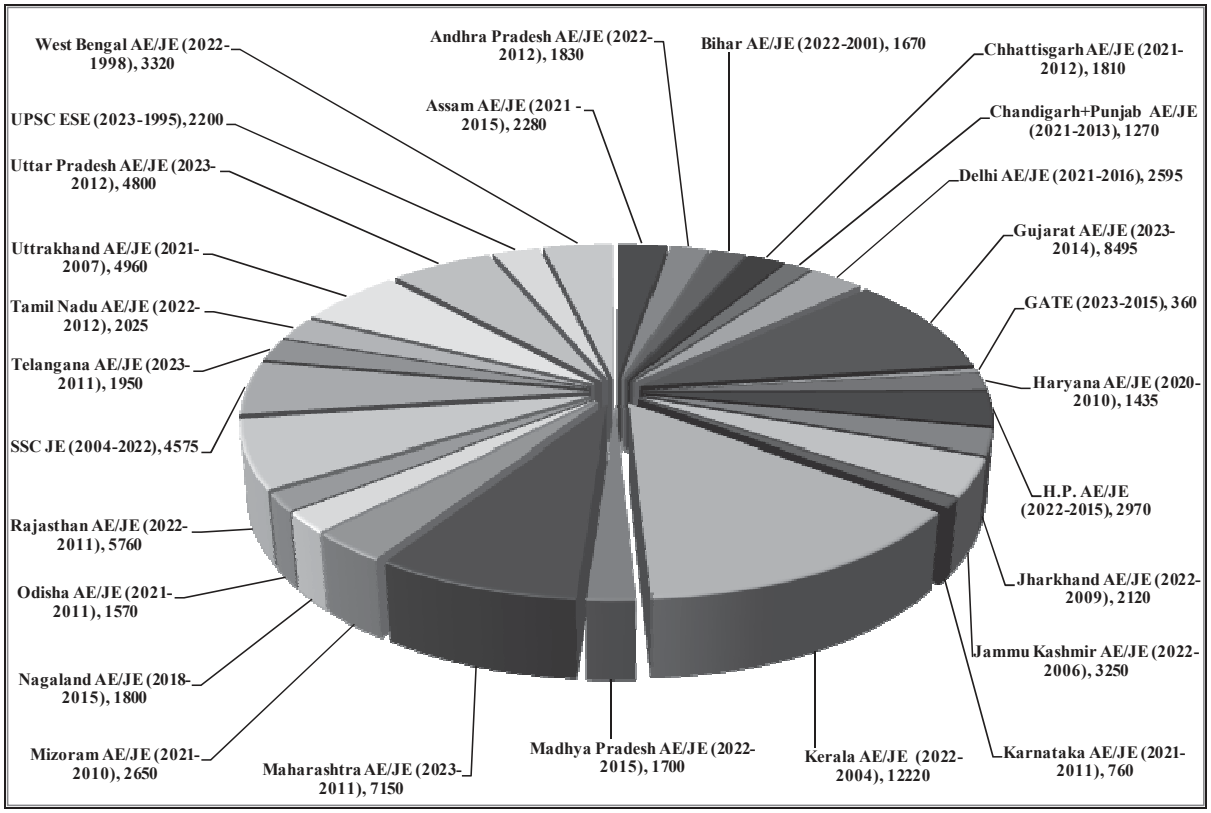
Basic principles of photogrammetry and remote sensing.

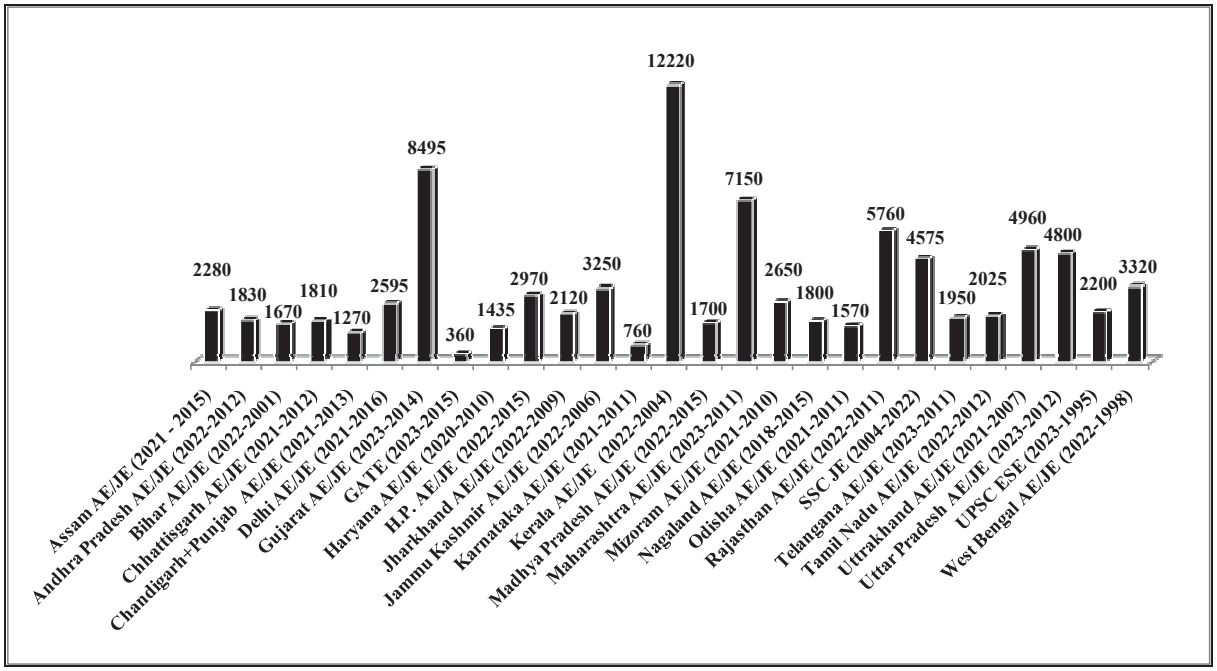
Introduction to Geographical information system.

Engineering Geology

Basic concepts of Engineering geology and its applications in projects such as dams, bridges and tunnels.

Trend Analysis of Exam (SSC JE/ ESE/State PSC & Other Exam) Papers Included Through Pie Chart and Bar Graph





SSC JE Civil Online Exam Topicwise Analysis Chart (2017-2022)

YEAR	SSC JE 1st March 2017 (M)	SSC JE 1st March 2017 (E)	SSC JE 2nd March 2017 (M)	SSC JE 2nd March 2017 (E)	SSC JE 3rd March 2017 (M)	SSC JE 3rd March 2017 (E)	SSC JE 4th March 2017 (M)	SSC JE 4th March 2017 (E)	SSC JE 22 Jan. 2018 (M)	SSC JE 22 Jan. 2018 (E)	SSC JE 23 Jan. 2018 (M)	SSC JE 23 Jan. 2018 (E)	SSC JE 24 Jan. 2018 (M)	SSC JE 24 Jan. 2018 (E)	SSC JE 25 Jan. 2018 (M)	SSC JE 25 Jan. 2018 (E)	SSC JE 27 Jan. 2018 (M)	SSC JE 27 Jan. 2018 (E)	SSC JE 29 Jan. 2018 (M)	SSC JE 29 Jan. 2018 (E)	SSC JE 23 Sep. 2019 (M)	SSC JE 23 Sep. 2019 (E)	SSC JE 25 Sep. 2019 (M)	SSC JE 28 Oct. 2020 (E)	SSC JE 29 Oct. 2020 (M)	SSC JE 30 Oct. 2020 (M)	SSC JE 30 Oct. 2020 (E)	SSC JE 11 Dec. 2020 (E)	SSC JE 23 March 2021 (M)	SSC JE 23 March 2021 (E)	SSC JE 14 November 2022 (M)	SSC JE 15 November 2022 (M)	SSC JE 15 November 2022 (E)	SSC JE 16 November 2022 (M)
HYDRAULICS	8	8	9	10	11	11	13	10	10	10	10	11	15	12	11	10	10	10	10	11	10	7	8	11	7	10	9	9	9	9	8	9	9	9
S.M.F.E	4	6	5	7	5	4	5	7	10	4	8	5	10	8	3	4	6	6	5	5	6	10	10	7	8	7	7	9	11	7	7	7	7	8
B.M	7	12	9	4	9	7	9	4	8	8	11	15	10	9	12	13	13	13	7	11	11	9	9	11	12	10	10	7	8	10	8	9	8	8
B.C.M.E	3	5	1	2	4	4	3	1	7	5	3	0	2	0	0	2	2	4	1	3	4	1	1	2	0	2	2	0	0	0	1	0	1	0
S.O.M	9	12	19	4	17	8	10	11	5	7	2	4	3	10	7	9	7	4	4	8	7	5	4	8	6	6	8	8	4	7	8	6	6	5
C.T	17	21	16	20	20	19	19	21	14	15	16	17	15	8	15	14	15	13	17	16	4	4	4	5	4	8	4	5	7	7	6	6	6	6
SURVEYING	10	10	10	9	9	10	10	10	13	9	9	9	10	10	8	8	10	9	10	7	10	8	10	11	9	9	10	10	10	10	10	10	10	11
P.H.E	1	1	1	1	2	2	3	6	5	2	3	2	7	5	5	3	3	3	3	2	8	5	8	8	8	7	7	9	8	10	8	9	10	9
R.C.C	12	3	12	18	3	14	5	2	3	10	8	13	10	11	10	11	10	8	10	11	7	10	12	7	9	6	10	10	7	7	6	10	6	9
MECHANICS	0	0	2	5	5	1	3	1	6	5	2	5	0	3	12	2	1	11	10	2	6	5	3	0	1	1	1	0	1	0	0	0	0	0
C.M.A.E.	1	0	0	1	1	1	0	0	2	0	3	0	0	2	0	0	0	0	0	1	0	0	0	0	0	0	0	1	0	0	1	2	4	1	0
E.C.V	3	2	9	2	4	2	0	0	10	10	10	9	10	9	12	10	7	9	11	7	10	9	10	10	12	12	11	13	11	10	9	7	10	9
H.R.B	3	2	0	6	3	3	4	7	2	5	2	2	0	5	1	3	3	2	3	4	5	11	7	8	9	8	8	8	7	9	12	8	9	10
D.S.M.S	20	16	5	9	5	13	14	17	2	8	11	4	7	6	1	10	11	6	7	10	4	4	4	4	5	5	3	5	8	4	6	5	9	6
I.E	2	2	2	2	2	1	2	3	3	2	2	4	1	2	3	1	2	2	2	2	8	12	10	8	10	9	9	7	9	9	9	10	8	10
TOTAL	100	100	100	100	100	100	100	100	100	100	100	100	100	100	100	100	100	100	100	100	100	100	100	100	100	100	100	100	100	100	100	100	100	100

***SMFE**-SOIL MECHANICS AND FOUNDATION ENGINEERING, **BM**-BUILDING MATEARIAL, **BCME**-BUILDING CONSTRUCTIONS AND MAINTENANCE ENGINEERING*

***SOM**-STRENGTHS OF MATERIAL, **CT**-CONCRETE TECHNOLOGY, **PHE**-PUBLIC HEALTH, ENGINEERING, **IE**-IRRIGATION ENGINEERING **R.C.C.**-REINFORCED CONCRETE TECHNOLOGY, **CMAED**-CONSTRUCTION MANAGEMENT, PUBLIC WORKS ACCOUNTS AND ENTREPRENEURSHIP DEVELOPMENT*

***ECV**-ESTIMATING, COSTING AND VALUATION, **HRB**-HIGHWAY RAILWAY AND BRIDGE ENGINEERING. **DSMS**- DESIGN OF STEEL AND MASONRY STRUCTURES*

ESE Subject-wise Analysis

Year	BMC	CPM	E.E.	FM	Hydrology	T.E.	Irrigation	RCC	SA	SOM	Soil Mechanics	Steel	Survey
2023	16	12	10	14	1	13	12	11	6	20	14	12	9
2022	13	11	13	13	2	11	8	14	9	16	14	14	12
2021	13	13	11	13	4	13	10	15	6	14	12	13	13
2020	10	12	14	13	4	14	4	16	6	17	13	13	14
2019	13	12	11	12	6	12	8	12	8	20	12	12	12
2018	13	3	16	33	7	10	4	9	10	15	16	9	5
2017	13	4	14	17	10	10	6	9	11	22	24	6	4
2016	30	16	20	53	4	12	10	16	8	27	20	11	13
2015	22	13	26	21	9	16	9	19	10	39	24	17	15
2014	26	16	22	22	15	12	9	13	8	30	22	25	20
2013	22	33	22	46	10	8	6	17	16	22	16	13	9
2012	27	8	26	31	10	5	3	18	11	29	29	21	22
2011	20	13	20	34	3	13	11	30	11	15	18	27	19
2010	20	24	15	26	10	17	9	11	14	24	27	26	17
2009	15	18	18	20	10	18	12	24	15	26	27	21	16
2008	27	12	21	16	6	28	3	15	18	21	30	21	15
2007	26	13	20	30	13	20	7	22	13	23	21	23	9
2006	20	11	18	29	15	19	8	25	20	20	20	23	12
2005	18	14	27	13	5	24	6	25	15	25	37	23	8
2004	21	13	29	22	13	15	6	20	17	20	30	24	10
2003	22	19	19	30	11	19	9	22	10	26	22	21	10

(T.E.) = Transportation Engineering

GATE Subject-wise Analysis

Year	E.E.	FM	Highway	Hydrology	Irrigation	RCC	SA	SOM	Soil Mechanics	Steel	Survey
2023 Set-1	8	5	3	3	2	4	5	4	10	2	3
2023 Set-2	10	5	5	2	1	2	4	7	10	1	3
2022 Set-1	8	5	6	2	1	3	4	4	9	1	4
2022 Set-2	9	6	7	2	2	3	4	6	10	2	2
2021 Set-1	10	5	4	4	2	4	5	7	10	2	3
2021 Set-2	9	4	4	4	2	8	2	7	9	2	4
2020 Set-1	8	6	4	1	1	5	6	6	11	2	2
2020 Set-2	8	3	7	4	3	4	7	3	9	3	4
2019 Set-1	6	5	4	3	3	4	4	5	13	5	7
2019 Set-2	8	9	9	3	4	2	6	7	15	4	4
2018 Set-1	10	9	9	5	0	9	2	7	14	3	4
2018 Set-2	10	7	9	4	1	7	1	5	15	5	4
2017 Set-1	10	8	9	3	2	5	5	6	13	2	4
2017 Set-2	11	8	7	4	2	3	1	8	13	2	6
2016 Set-1	10	7	6	2	0	6	3	6	17	4	5
2016 Set-2	10	7	7	3	1	5	3	7	15	4	5
2015 Set-1	6	12	10	2	1	5	4	5	12	4	6
2015 Set-2	10	9	9	2	2	7	0	6	15	4	6
2014 Set-1	10	13	10	2	0	7	8	2	12	4	5
2014 Set-2	10	10	9	3	2	3	7	9	14	2	5
2013	8	9	9	6	2	5	9	6	14	5	5
2012	10	4	10	7	2	8	0	9	15	3	3
2011	9	7	11	5	2	8	0	7	15	5	2
2010	9	7	7	1	4	5	3	9	17	4	3
2009	14	7	10	4	3	6	2	12	16	6	5
2008	14	15	20	1	6	12	6	17	25	5	9
2007	15	16	16	6	4	12	9	13	23	6	10
2006	15	17	14	6	3	11	6	21	21	6	10
2005	20	17	12	6	8	14	10	8	24	9	0
2004	21	26	15	4	3	12	9	13	26	12	0
2003	22	19	9	11	4	13	12	12	28	10	0

Appendix

Units		
Measurement	**Units**	**Symbol**
Length	Meter	m
Mass	Kilogram	kg
Force	Newton	N
Time	Second	S
Electric current	Ampere	A
Temperature	Kelvin	K
Luminous Intensity	Candela	Cd

Prefixes-

Greek Prefixes		
Prefix	**symbol**	**value**
Deca	da	10^{1}
Hecto	h	10^{2}
Kilo	K	10^{3}
Mega	M	10^{6}
Giga	G	10^{9}
Tera	T	10^{12}
Peta	P	10^{15}
Exa	E	10^{18}
Zetta	Z	10^{21}
Yotta	Y	10^{24}

Latin Prefixes		
Prefix	**symbol**	**value**
Deci	d	10^{-1}
Centi	c	10^{-2}
Milli	m	10^{-3}
Micro	μ	10^{-6}
Nano	n	10^{-9}
Pico	p	10^{-12}
Femto	f	10^{-15}
Atto	a	10^{-18}
Zepto	z	10^{-21}
Yocto	y	10^{-24}

Units Conversion-

Length			
1 m	= 3.281 ft	1 ft.	= 0.3048 m
1 km	= 0.622 mile	1 mile	= 1.6093 km
1 cm	= 0.394 inch	1 inch	= 2.54 cm
1 mm	= 10^3 micron	1 micron	= 10^{-6} m

Area			
1 m^2	= 10.761 ft^2	1 ft^2	= 0.093 m^2
1 km^2	= 10^6 m^2 = 100 Ha	1 $mile^2$	= 2.59 km^2
	= 247 acres	= 251 Ha= 640 acres	
1 Ha	= 10^4 m^2 = 2.47 acres	1 acre = 4840 sq. yards	

Volume			
1 m^3	= 35.307 ft^3	1 ft^3	= 0.02832 m^3

TRIGONOMETRIC TABLE-

θ	0°	30°	45°	60°	90°
sinθ	0	$\frac{1}{2}$	$\frac{1}{\sqrt{2}}$	$\frac{\sqrt{3}}{2}$	1
cosθ	1	$\frac{\sqrt{3}}{2}$	$\frac{1}{\sqrt{2}}$	$\frac{1}{2}$	0
tanθ	0	$\frac{1}{\sqrt{3}}$	1	$\sqrt{3}$	∞
cotθ	∞	$\sqrt{3}$	1	$\frac{1}{\sqrt{3}}$	0
secθ	1	$\frac{2}{\sqrt{3}}$	$\sqrt{2}$	2	∞
cosecθ	∞	2	$\sqrt{2}$	$\frac{2}{\sqrt{3}}$	1

Reciprocal Identities	Pythagorean	Half-Angle Formulas
$\operatorname{cosec}\theta = \frac{1}{\sin\theta}$	$\sin^2\theta + \cos^2\theta = 1$	$\sin\left(\frac{\theta}{2}\right) = \pm\sqrt{\frac{1-\cos\theta}{2}}$
$\sec\theta = \frac{1}{\cos\theta}$	$\sec^2\theta = 1 + \tan^2\theta$	$\cos\left(\frac{\theta}{2}\right) = \pm\sqrt{\frac{1+\cos\theta}{2}}$
$\cot\theta = \frac{1}{\tan\theta}$	$\sec^2\theta = 1 + \cot^2\theta$	$\tan\left(\frac{\theta}{2}\right) = \frac{1-\cos\theta}{\sin\theta}$

- $\boxed{\sin^2\theta + \cos^2\theta = 1}$
- $\boxed{\sec^2\theta = 1 + \tan^2\theta}$
- $\boxed{\operatorname{cosec}^2\theta = 1 + \cot^2\theta}$

Product to Sum Formulas-

- $\sin x \sin y = \frac{1}{2}\left[\cos(x-y) - \cos(x+y)\right]$
- $\cos x \cos y = \frac{1}{2}\left[\cos(x-y) + \cos(x+y)\right]$
- $\sin x \cos y = \frac{1}{2}\left[\sin(x+y) + \sin(x-y)\right]$
- $\cos x \sin y = \frac{1}{2}\left[\sin(x+y) - \sin(x-y)\right]$

Sum to Product Formulas-

- $\sin x + \sin y = 2\sin\left(\frac{x+y}{2}\right)\cos\left(\frac{x-y}{2}\right)$
- $\sin x - \sin y = 2\sin\left(\frac{x-y}{2}\right)\cos\left(\frac{x+y}{2}\right)$
- $\cos x + \cos y = 2\cos\left(\frac{x+y}{2}\right)\cos\left(\frac{x-y}{2}\right)$
- $\cos x - \cos y = -2\sin\left(\frac{x+y}{2}\right)\sin\left(\frac{x-y}{2}\right)$

Angle Addition Formulas-

- $\sin(x+y) = \sin x \cos y + \cos x \sin y$
- $\sin(x-y) = \sin x \cos y - \cos x \sin y$
- $\cos(x+y) = \cos x \cos y - \sin x \sin y$
- $\cos(x-y) = \cos x \cos y + \sin x \sin y$

$$\tan(x+y) = \frac{\tan x + \tan y}{1 - \tan x \tan y} \qquad \tan(x-y) = \frac{\tan x - \tan y}{1 + \tan x \tan y}$$

$$\cot(x+y) = \frac{\cot x \cot y - 1}{\cot y + \cot x}, \qquad \cot(x-y) = \frac{\cot x \cot y + 1}{\cot y + \cot x}$$

Double Angle Formulas-

$$\sin 2\theta = 2\sin\theta\cos\theta, \qquad \sin 2\theta = \frac{2\tan\theta}{1+\tan^2\theta}$$

$$\cos 2\theta = \cos^2\theta - \sin^2\theta = 2\cos^2\theta - 1 = 1 - 2\sin^2\theta, \qquad \cos 2\theta = \frac{1-\tan^2\theta}{1+\tan^2\theta}$$

$$\tan 2\theta = \frac{2\tan\theta}{1-\tan^2\theta}, \qquad \cot 2\theta = \frac{\cot^2\theta - 1}{2\cot\theta}$$

$2\sin x \cos y = \sin(x+y) + \sin(x-y)$
$2\cos x \sin y = \sin(x+y) - \sin(x-y)$
$2\cos x \cos y = \cos(x+y) + \cos(x-y)$
$2\sin x \sin y = \cos(x-y) - \cos(x-y)$

Law of Cosines-

- $a^2 = b^2 + c^2 - 2bc\cos x$
- $b^2 = a^2 + c^2 - 2ac\cos y$
- $c^2 = a^2 + b^2 - 2ab\cos z$

- Sridharacharya formula- $x = \frac{-b \pm \sqrt{b^2 - 4ac}}{2a}$
- $(a+b)^2 = a^2 + b^2 + 2ab$
- $(a-b)^2 = a^2 + b^2 - 2ab = (a+b)^2 - 4ab$
- $a^2 - b^2 = (a+b)(a-b)$
- $(a+b)^3 = a^3 + b^3 + 3ab(a+b)$
- $(a-b)^3 = a^3 - b^3 - 3ab(a-b)$
- $a^3 - b^3 = (a+b)(a^2 + b^2 - ab) = (a-b)(a^2 + b^2 + ab)$

Arithmetic Progression Formulas-

- n^{th} term of AP, $T_n = a + (n-1)d$
- Some of 'n' terms of AP, $S_n = \frac{n}{2}(2a + (n-1)d$
- If I^{st} and last terms are known then, $S_n = \frac{n}{2}(a + l)$

Geometric Progression Formulas-

a, ar, ar^2, ar^3, ...

n^{th} term, $a_n = a.n^{n-1}$

- Sum of n^{th} terms of G.P.-

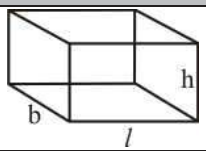
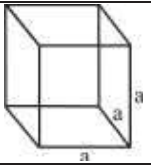
(i) $S_n = \frac{a.(r^n - 1)}{(r-1)}$ If r > 1

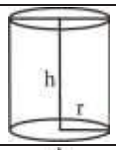
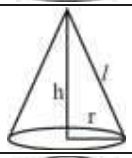
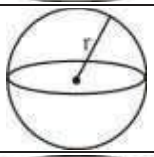
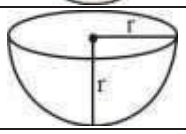
(ii) $S_n = \frac{a.(1-r^n)}{(1-r)}$ If r < 1

(iii) $S_n = n.a$ If r = 1

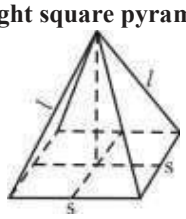
- Sum of infinite term-

$S_\infty = \frac{a}{1-r}$ If $-1 < r < 1$

Name of the solid	Figure	Volume	Lateral/Curved surface area	Total surface area
Cuboid		*l*bh	2lh + 2bh or 2h(*l* + b)	2*l*h + 2bh + 2lb or 2(*l*h + bh + *l*b)
Cube		a^3	$4a^2$	$4a^2 + 2a^2$ or $6a^2$

Right circular cylinder		$\pi r^2 h$	$2\pi rh$	$2\pi rh + 2\pi r^2$ or $2\pi r\,(h + r)$
Right circular cone		$\frac{1}{3}\pi r^2 h$	πrl	$\pi rl + \pi r^2$ or $\pi r(l + r)$
Sphere		$\frac{4}{3}\pi r^3$	$4\pi r^2$	$4\pi r^2$
Hemisphere		$\frac{2}{3}\pi r^3$	$2\pi r^2$	$2\pi r^2 + \pi r^2$ or $3\pi r^2$

Right square pyramid

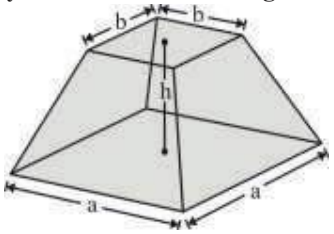


$$V = \frac{1}{3}s^2h$$

Parabolic Cone

$$V = \frac{\pi d^2 h}{8}$$

Truncated Pyramid/Column Footing-



Case-1 If 'a' and 'b' is the side of pyramid.

$$\boxed{V = \frac{1}{3}h(a^2 + b^2 + ab)}$$

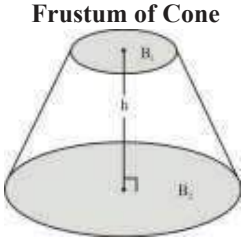
Case-2 If A_1 and A_2 is the area of bottom and top surface.

$$\boxed{V = \frac{1}{3}h\left[A_1 + A_2 + \sqrt{A_1A_2}\right]}$$

Where, $A_1 = a \times a = a^2$

$A_2 = b \times b = b^2$

Frustum of Cone



$$\boxed{V = \frac{1}{3}h\left(B_1 + B_2 + \sqrt{B_1B_2}\right)}$$

Case-1 If dia. of bottom and top surface is b & d then-

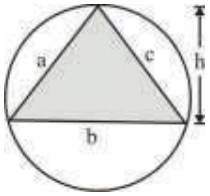
$$\boxed{V = \frac{\pi h}{12}\left[b^2 + d^2 + bd\right]}$$

Case-2 If B_1 & B_2 is top and bottom area of frustum.

$$\boxed{V = \frac{1}{3}h\left(B_1 + B_2 + \sqrt{B_1B_2}\right)}$$

Where, $B_1 = \frac{\pi}{4}b^2$ and $B_2 = \frac{\pi}{4}d^2$

Triangle-



$$\boxed{A = \frac{1}{2}bh}, \quad \boxed{A = \frac{abc}{4R} = rs}$$

$$\boxed{A = \sqrt{s(s-a)(s-b)(s-c)}}$$

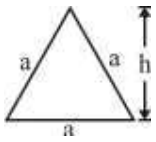
Semi-perimeter, $\boxed{s = \frac{a+b+c}{2}}$,

Where, a, b, c are the three sides of triangle

h = Height

R = Radius of circumscribed circle

Equilateral Triangle-

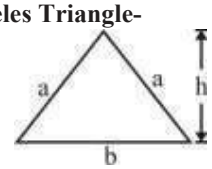


$$A = \frac{\sqrt{3} \times a^2}{4} = 0.433a^2, \qquad h = \frac{\sqrt{3}}{2} \times a$$

Where,

a = Side of triangle, h = Height of triangle

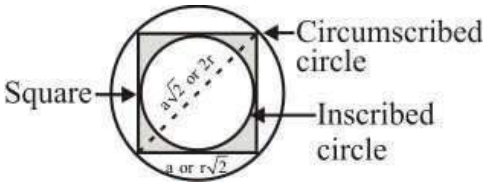
Isosceles Triangle-



$$A = \frac{b}{4}\sqrt{4a^2 - b^2}$$

Where, a = Side of triangle, b = Base of triangle

Square-



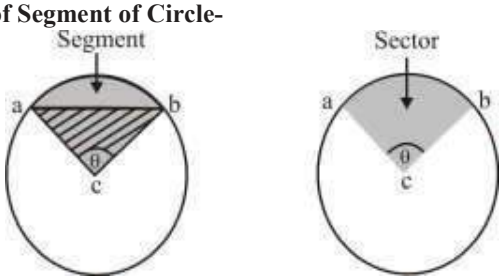
(i) $A = a^2$

(ii) Diagonal, $d = a\sqrt{2} = 1.414a$

(iii) A = 1.2732 × Area of inscribed circle
= 0.6366 × Area of circumscribed circle

(iv) Dia. of circle, circumscribed about square
= 1.414 × a^2

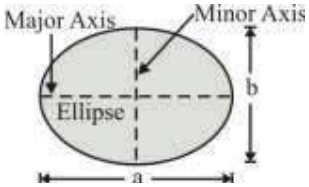
Area of Segment of Circle-



Area of segment = Area of sector – Area of triangle.

If θ is in degrees then	**If θ is in radians**
area of sector = $\frac{\pi r^2 \theta}{360°}$	then area of sector = $\frac{1}{2}r^2\theta$
Area of segment, = $r^2\left(\frac{\pi\theta}{360°} - \frac{\sin\theta}{2}\right)$	**Area of segment,** = $\frac{1}{2}r^2(\theta - \sin\theta)$

Ellipse-

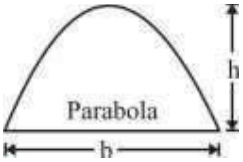


$$A = \frac{\pi}{4}(a.b) = 0.7854(a.b)$$

a = Major axis, b = Minor axis

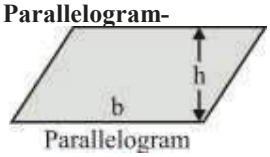
Perimeter = $3.1416\left(\frac{a+b}{2}\right)$

Parabola-



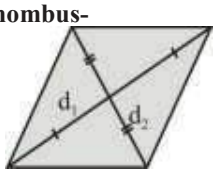
$A = \text{Base} \times \frac{2}{3}\text{Height} = \frac{2}{3}bh$

Parallelogram-



$A = \text{base} \times \text{height} = b \times h$

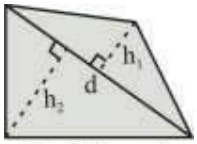
Rhombus-



$A = \frac{1}{2}d_1 \times d_2$

Where, d_1, d_2 are the two diagonals.

Quadrilateral-

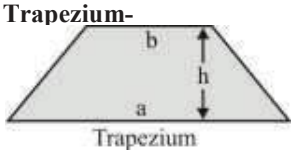


$A = \frac{1}{2}d(h_1 + h_2)$

Where, d = Diagonal

A_1, A_2 are the offsets from the Diagonal

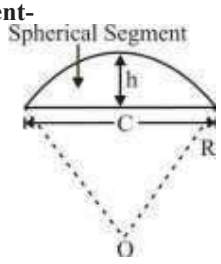
Trapezium-



$A = \frac{1}{2}[\text{Sum of both parallel arms}] \times \text{Height}$

$A = \frac{1}{2}(a+b).h$

Spherical Sequent-



(i) Volume (V) = $\frac{\pi h^2}{3}(3R - h)$

$= \frac{\pi h}{24}(3C^2 + 4h^2)$

(ii) Spherical surface = $2\pi Rh$

(iii) Total surface = Spherical surface + $\frac{\pi C^2}{4}$

AMENDMENT NO. 5 – JULY, 2019
TO
IS 456: 2000 PLAIN AND REINFORCE CONCRETE - CODE OF PRACTICE

S. No.	Clause	Before Amendment	After Amendment
1	5.1	**Cement–**	
		Types of recommended cement:	**Note-** According to amendment No. 5 July 2019 Clause No.5.1 (b) and (c) Delete.
		(a) 33 grade ordinary Portland cement (OPC) conforming to IS 269	
		(b) 43 grade ordinary Portland cement (OPC) conforming to IS 8112	
		(c) 53 grade ordinary Portland cement (OPC) conforming to IS 12269	
		(d) Rapid hardening Portland cement conforming to IS 8041	
		(e) Portland slag cement conforming to IS 455	
		(f) Portland pozzolana cement (fly ash based) (PPC) conforming to IS 1489 (Part-I)	
		(g) Portland pozzolana cement (calcined clay based) conforming to IS 1489 (Part-II)	
		(h) Hydrophobic cement conforming to IS 8043	
		(j) Low heat portland cement conforming to IS 12600	
		(k) Sulphate resisting portland cement conforming to IS 12330	
2.	5.2	**Mineral Admixtures**	**Mineral Admixture -** 'Mineral admixtures listed below may be used along with ordinary Portland cement. Uniform blending of the mineral admixtures with the cement should be ensured.'
3.	5.2.1	**Pozzolanas -** Pozzolanic materials conforming to relevant Indian Standards may be used with the permission of the engineer-in-charge, provided uniform blending with cement is ensured.	**Pozzolanas -** Pozzolanic materials conforming to relevant Indian Standards may be used with the permission of the engineer-in-charge.
4.	5.2.1.1.	**Fly ash (pulverized fuel ash) -** Fly ash conforming to Grade 1 of IS 3812 may be used as part replacement of ordinary Portland cement provided uniform blending with cement is ensured.	**Fly ash (pulverized fuel ash) -** Fly ash conforming to Grade 1 of IS 3812 may be used as part replacement of ordinary Portland cement.
5.	5.2.1.2	**Silica fume -** Silica fume conforming to a standard approved by the deciding authority may be used as part replacement of cement provided uniform blending with the cement is ensured.	**Silica fume -** Silica fume conforming to a standard approved by the deciding authority may be used as part replacement of cement.
6.	5.2.1.4	**Metakaoline -** Metakaoline having fineness between 700 to 900 m^2/kg may be used as pozzolanic material in concrete.	**Metakaoline -** Metakaolin conforming to IS 16354 may be used as part replacement of ordinary Portland cement,'
7.	5.2.2	**Ground granulated Blast Furnace Slag–** Ground granulated blast furnace slag obtained by grinding granulated blast furnace slag conforming to IS 12089 may be used as part replacement of ordinary Portland cements Provided uniform blending with cement is ensured.	**Ground granulated Blast Furnace Slag–** Ground granulated blast furnace slag conforming to IS 16714 may be used as part replacement of ordinary Portland cement.
		Newly added amendments	
8.	5.2.3	**Precautions** (***after Amendment No.5 July 2019***)	
9.	5.2.3.1	For concrete made with mineral admixtures, the setting time and rate of gain of strength may be different from those of concrete made with ordinary Portland cement alone (***after Amendment No.5 July 2019***)	

10.	**5.2.3.2**	Concrete containing mineral admixtures may exhibit and increase in plastic shrinkage cracking because of its low bleeding characteristics. The problem may be avoided by ensuring that such concrete is protected against drying, both during and after finishing. **(*after Amendment No.5 July 2019*)**
11.	**5.2.3.3**	Some other properties of concrete such as modulus of elasticity, tensile strength, creep and shrinkage are not likely to be significantly different. For design purposes, it will be sufficiently accurate to adopt the same values as those used for concrete made with ordinary Portland cement alone. **(*after Amendment No.5 July 2019*)**
12.	**5.2.3.4**	Mixes that contain very fine mineral admixtures such as silica fume, can be sticky and difficult to finish. **(*after Amendment No.5 July 2019*)**
13.	**5.2.3.5**	Concrete made using blended cements such as Portland Pozzolana cement and Portland slag cement shall also adhere to **5.2.3.1, 5.2.3.2** and **5.2.3.3.** **(*after Amendment No.5 July 2019*)**
14.	**11.0 Formwork**	

Type Formwork	Minimum Period Before Striking Formwork
(a) Vertical formwork to columns, walls, beams	16–24 h **RRB SSE Secundrabad-01-09-2015 (Shift-I)**
(b) Soffit formwork to slabs (Props to be refixed immediately after removal of formwork)	3 days
(c) Soffit formwork to beams (Props to be refixed immediately after removal of formwork)	7 days
(d) Props to slabs	
(i) Spanning up to 4.5 m	7 days **UPPCL JE 02-01-2021(Shift-I)** **SSB HP-18-11-2018** **RRB SSE Secundrabad-01-09-2015 (Shift-II)**
(ii) Spanning over 4.5 m	14 days **LMRC AE-2017 (Shift-I)**
(e) Props to beams and arches	
(i) Spanning up to 6 m	14 days **RRB SSE Online-01-09-2015 (Shift-II)**
(ii) Spanning over 6 m	21 days

Type of Formwork	minimum Before	Period
	for concrete made using OPC	For concrete Made Using Cement Other than OPC or Using Mineral Admixtures Like Fly Ash and slag
i) Vertical formwork to columns, walls, beams	16–24h	16–24 h
ii) Soffit formwork to slabs (Props to be refixed immediately after removal of formwork)	3 days	7 days
iii) Soffit form work to beams (props to be refixed immediately after removal of formwork)	7 days	10 days
iv) Props to slabs: 1) Spanning up to 4.5 m 2) spanning over 4.5 m	7 days 14 days	10 days 14 days

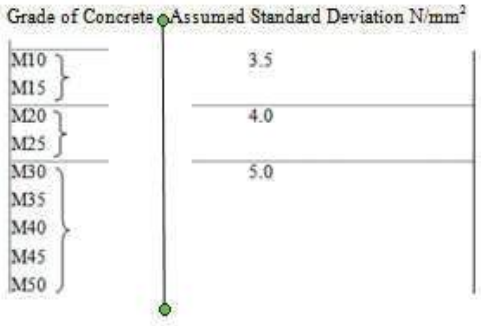
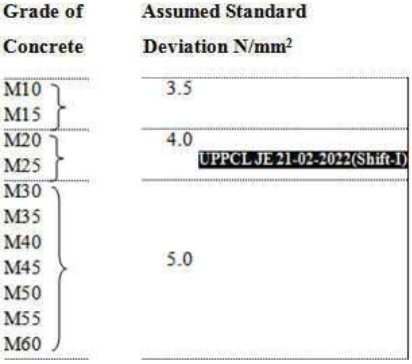
			v) Props to beams and arches: 1) Spanning up to 6 m 2) Spanning over 6 m	14 days 21 days	14 days 21 days
			Note- Utmost care shall be taken to provide props. The props shall be provided immediately after stripping each shuttering panel and not after stripping all the panels of the entire slab		
15.	**11.3.1**	In case of use of cements other than OPC or in case of use of mineral admixtures like fly ash and slag, in lieu of the minimum period specified in	col 3, the stripping of formwork may be done in accordance with the provisions of **11.3.1** col 2, provided concrete cube testing is done to ensure that the following minimum strength is achieved: (a) 3 days : 45 percent of specified strength (b) 7 days : 60 percent of specified strength (c) 14 days : 85 percent of specified strength		
16.	**13.3.1**	Concrete shall be compacted using mechanical vibrators complying with **IS 2505, IS 2506, IS 2514** and **IS 4656**. Over vibration and under vibration of concrete are harmful and should be avoided. Vibration of very wet mixes should also be avoided.	Concrete shall be compacted using mechanical vibrators complying with **IS 2505, IS 2506** and **IS 2514**.		

AMENDMENT NO. 4 – MAY, 2013
TO
IS 456: 2000 PLAIN AND REINFORCE CONCRETE - CODE OF PRACTICE

S. No.	Clause	Before Amendment	After Amendment
1.	**5.3 Aggregates**	Aggregates shall comply with the requirements of IS 383. As far as possible preference shall be given to natural aggregates.	Aggregates shall comply with the requirements of IS 383
2.	**5.3.4**	Coarse and fine aggregate shall be batched separately. All-in-aggregate may be used only where specifically permitted by the engineer-in-charge.	Coarse and fine aggregate shall be batched separately.
3.	**5.4 Water**	Water used for mixing and curing shall be clean and free from injurious amounts of oils, acids, alkalis, salts, sugar, organic materials or other substances that may be deleterious to concrete or steel.	Water, natural or treated, used for mixing and curing shall be clean and free from injurious amounts of oils, acids, alkalis, salts, sugar, organic materials or other substances that may be deleterious to concrete or steel.
4.	**5.4.3 Sea Water**	Mixing or curing of concrete with sea water is not recommended because of presence of harmful salts in sea water. Under unavoidable circumstances sea water may be used for mixing or curing in plain concrete with no embedded steel after having given due consideration to possible disadvantages and precautions including use of appropriate cement system.	Sea water shall not be used for mixing or curing of concrete because of presence of harmful salts. Under unavoidable circumstances sea water may be used for mixing or curing in plain concrete with no embedded steel after having given due consideration to possible disadvantages and precautions including use of appropriate cement system.
5.	**5.5.5 New Clause added**		The amount of admixture added to a mix shall be recorded in the production record. Redosing of admixtures is not normally permitted. In special circumstances, if necessary, additional dose of admixture may be added at a project site and mixed adequately in mixer itself to regain the workability of concrete with the mutual agreement between the producer/supplier and the purchaser/user of concrete. However the producer/supplier shall assure the ultimate quality of concrete supplied by him and maintain record of quantity and time of addition.

<table>
<tr>
<td>6.</td>
<td>Table 2 – Grades of Concrete</td>
<td>
<table>
<tr><th>Group</th><th>Grade designation</th><th>Specified characteristic compressive strength of 150 mm cube at 28 days in N/mm^2 UPSSSC JE 16-4-2022</th></tr>
<tr><td rowspan="3">Ordinary concrete</td><td>M 10</td><td>10</td></tr>
<tr><td>M 15</td><td>15 SSC JE-03-03-2017 (Even.)</td></tr>
<tr><td>M 20</td><td>20 NBCC JE-2018 (Morn.)</td></tr>
<tr><td rowspan="7">Standard Concrete</td><td>M 25</td><td>25</td></tr>
<tr><td>M 30</td><td>30</td></tr>
<tr><td>M 35</td><td>35</td></tr>
<tr><td>M 40</td><td>40</td></tr>
<tr><td>M 45</td><td>45</td></tr>
<tr><td>M 50</td><td>50</td></tr>
<tr><td>M 55</td><td>55</td></tr>
<tr><td rowspan="5">High strength Concrete</td><td>M 60</td><td>60</td></tr>
<tr><td>M 65</td><td>65</td></tr>
<tr><td>M 70</td><td>70</td></tr>
<tr><td>M 75</td><td>75</td></tr>
<tr><td>M 80</td><td>80</td></tr>
</table>
Note-
(1) In the designation of concrete mix M refers to the mix and the number to the specified compressive strength of 150 mm size cube at 28 days, expressed in N/mm^2
(2) For concrete of compressive strength greater than M 55, design parameters given in the standard may not be applicable and the value may be obtained from specialized literature and experimenal results.
</td>
<td>
<table>
<tr><th>Group</th><th>Grade designation</th><th>Specified characteristic compressive strength of 150 mm cube at 28 days in N/mm^2 UPSSSC JE 16-4-2022</th></tr>
<tr><td rowspan="3">Ordinary concrete</td><td>M 10</td><td>10</td></tr>
<tr><td>M 15</td><td>15 Andman&Nicobar APWD JE Civil 27-7-2019 SSC JE-03-03-2017 (Even.)</td></tr>
<tr><td>M 20</td><td>20 KPSC AE Civil 26-2-2023 NBCC JE-2018 (Morn.)</td></tr>
<tr><td rowspan="8">Standard Concrete</td><td>M 25</td><td>25 Andman & Nicobar Plan.Asst. 6-3-2023 (Shift-I)</td></tr>
<tr><td>M 30</td><td>30</td></tr>
<tr><td>M 35</td><td>35</td></tr>
<tr><td>M 40 KPSC AE Civil 26-2-2023</td><td>40</td></tr>
<tr><td>M 45</td><td>45</td></tr>
<tr><td>M 50</td><td>50</td></tr>
<tr><td>M 55</td><td>55</td></tr>
<tr><td>M 60</td><td>60</td></tr>
<tr><td rowspan="6">High strength Concrete</td><td>M 65</td><td>65</td></tr>
<tr><td>M 70</td><td>70</td></tr>
<tr><td>M 75</td><td>75</td></tr>
<tr><td>M 80</td><td>80</td></tr>
<tr><td>M 85</td><td>85</td></tr>
<tr><td>M 90</td><td>90</td></tr>
<tr><td>M 100</td><td>100</td></tr>
</table>
In this amendment, Classification of Concrete has been changed. M60Gr. has been shifted to Standard concrete and from Grades M85 to M100 are added to High strength concretes. In note to M55 is replaced with M60.
</td>
</tr>
<tr>
<td>7.</td>
<td>8.1 General</td>
<td>A durable concrete is one that performs satisfactorily in the working environment during its anticipated exposure conditions during service. The materials and mix proportions specified and used should be such as to maintain its integrity and, if applicable, to protect embedded metal from corrosion.</td>
<td>A durable concrete is one that performs satisfactorily in the working environment during its anticipated exposure conditions during service life. The materials and mix proportions specified and used should be such as to maintain its integrity and, if applicable, to protect embedded metal from corrosion.</td>
</tr>
<tr>
<td>8.</td>
<td>NOTES to Table 5 Minimum Cement Content, Maximum</td>
<td>Cement content prescribed in this table is irrespective of the grades of cement and it is inclusive of additions mentioned in 5.2. The additions such as fly ash or ground granulated blast furnace slag may be taken into account in the concrete composition with respect to the cement</td>
<td>Cement content prescribed in this table is irrespective of grades and types of cement and is inclusive of mineral admixtures mentioned in 5.2. The mineral admixtures such as fly ash or ground granulated blast furnace slag shall be taken into account in</td>
</tr>
</table>

	Water-Cement Ratio and Minimum Grade of Concrete for Different Exposures with Normal Weight Aggregates of 20 mm Nominal Maximum Size	content and water-cement ratio if the suitability is established and as long as the maximum amounts taken into account do not exceed the limit of pozzolona and slag	the concrete composition with respect to the cement content and water-cement ratio not exceeding the limit of fly ash and slag specified in IS 1489(Part I) and IS 455 respectively, beyond which these additions though permitted, shall not be considered for these purposes.
9.	NOTES to Table 5 – *Note 3 added*	Only 2 note items mentioned.	3. The minimum cement content, maximum free water-cement ratio and minimum grade of concrete are individually related to exposure.
10.	**8.2.5.4 Alkali-aggregate reaction**	b) Use of low alkali ordinary Portland cement having total alkali content not more than 0.6 percent (as Na_2O equivalent). Further advantage can be obtained by use of fly ash (Grade 1) conforming to IS 3812 or granulated blast furnace slag conforming to IS 12089 as part replacement of ordinary Portland cement (having total alkali content as Na_2O equivalent not more than 0.6 percent), provided fly ash content is at least 20 percent or slag content is at least 50 percent.	b) Use of low alkali ordinary Portland cement having total alkali content not more than 0.6 percent (as Na_2O equivalent). Further advantage can be obtained by use of flyash conforming to IS 3812 (Part I) or ground granulated blast furnace slag conforming to IS 12089 as part replacement of ordinary Portland cement (having total alkali content as Na_2O equivalent not more than 0.6 percent), provided fly ash content is at least 25percent or slag content is at least 50 percent.
11.	**8.2.6.2 Drainage**	At sites where alkali concentrations are high or may become very high, the ground water should be lowered by drainage so that it will not come into direct contact with the concrete. Additional protection may be obtained by the use of chemically resistant stone facing or a layer of plaster of Paris covered with suitable fabric, such as jute thoroughly impregnated with bituminous material.	At sites where alkali concentrations are high or may become very high, the ground water should be lowered by drainage so that it will not come into direct contact with the concrete. Additional protection may be obtained by the use of suitable impermeable barriers.
12.	**9.2 Design Mix Concrete 9.2.1**	As the guarantor of quality of concrete used in the construction, the constructor shall carry out the mix design and the mix so designed (not the method of design) shall be approved by the employer within the limitations of parameters and other stipulations laid down by this standard.	As the guarantor of quality of concrete used in the construction, the constructor shall carry out the mix design and the mix so designed (not the method of design) shall be approved by the employer within the limitations of parameters and other stipulations laid down by this standard. If so desired, the employer shall be provided with supporting data including graphs showing strength versus water cement ratio for range of proportions, complete trial mix proportioning details to substantiate the choice of cement content, fine and coarse aggregate content, water, mineral admixtures, chemical admixtures etc.,
13.	**9.2.2**	The mix shall be designed to produce the grade of concrete having the required workability and a characteristic strength not less than appropriate values given in Table 2. The target mean strength of concrete mix should be equal to the characteristic strength plus 1.65 times the standard deviation.	The mix shall be designed to produce the grade of concrete having the required workability and a characteristic strength not less than appropriate values given in Table 2. Proportion/grading of aggregates shall be made by trial in such a way as to make densest possible concrete. The target mean strength of concrete mix should be equal to the characteristic strength plus 1.65 times the standard deviation.

14.	**Table 8 Assumed Standard Deviation**	 **NOTES -** The above values correspond to the site control having proper storage of cement; weight batching of al materials; controlled addition of water; regular checking of all materials, aggregate gradings and moisture content; and periodical cheacking of workability and strength. Where there is deviation from the above the values given in the above table shall be increased by IN/mm^2.	 **NOTES -** 1. The above values correspond to the site control having proper storage of cement; weight batching of al materials; controlled addition of water; regular checking of All materials, aggregate gradings and moisture content; and periodical cheacking of workability and strength. Where there is deviation from the above the values given in the above table shall be increased by 1N/mm^2 2. for grade above M60, the standard deviation shall be established by actual trials based on assumed proportion, before finalizing the mix. 3. In this amendment, M55 and M60 has been added in the amended version to the Grade of Concrete. Also note 2 is added
15	**10.2 Batching**	To avoid confusion and error in batching, consideration should be given to using the smallest practical number of different concrete mixes on any site or in any one plant. In batching concrete, the quantity of both cement and aggregate shall be determined by mass; admixture, if solid, by mass; liquid admixture may however be measured in volume or mass; water shall be weighed or measured by volume in a calibrated tank (see also IS 4925). Ready-mixed concrete supplied by ready-mixed concrete plant shall be preferred. For large and medium project sites the concrete shall be sourced from ready mixed concrete plants or from on site or off site batching and mixing plants (see IS 4926).	To avoid confusion and error in batching, consideration should be given to using the smallest practical number of different concrete mixes on any site or in any one plant. In batching concrete, the quantity of both cement and aggregate shall be determined by mass; admixture, if solid, by mass; liquid admixture may however be measured in volume or mass; water shall be weighed or measured by volume in a calibrated tank (see also IS 4925). For large and medium project sites, the concrete shall be sourced from Ready mixed concrete plants or from captive on site or off site automatic batching and mixing plants. The concrete produced and supplied by ready-mixed concrete plants shall be in accordance with IS 4926. In case of concrete from captive on site or off site automatic batching and mixing plants, similar quality control shall be followed.
16	**10.2.1**	Except where it can be shown to the satisfaction of the engineer-in-charge that supply of properly graded aggregate of uniform quality can be maintained over a period of work, the grading of aggregate should be controlled by obtaining the coarse aggregate in different sizes and blending them in the right proportions when required, the different sizes being stocked in separate stock-piles. The material should be stock-piled for several hours preferably a day before use. The grading of coarse and fine aggregate should be checked as frequently as possible, the frequency for a given job being determined by the engineer-in charge to ensure that the specified grading is maintained.	The grading of aggregate shall be controlled by obtaining the coarse aggregate in different sizes and blending them in right proportions, the different sizes being stocked in separate stock piles. The material should be stock-piled for several hours preferably a day before use. The grading of coarse and fine aggregate should be checked as frequently as possible, the frequency for a given job being determined by the engineer-in charge to ensure that the specified grading is maintained.

17	**10.2.2**	The accuracy of the measuring equipment shall be within + 2 percent of the quantity of cement being measured and within + 3 percent of the quantity of aggregate, admixtures and water being measured.	The accuracy of measuring equipment shall be within ±2 percent of the quantity of cement and mineral admixtures being measured and within ±3percent of the quantity of aggregate, chemical admixtures and water being measured. In a batching plant, the concrete production equipment shall be calibrated initially at the time of installation or reconditioning of the equipment and subsequently at the following intervals: a) Mechanical/knife edge systems : At least once every two months b) Electrical / load cell systems : At least once every three months
18	**10.2.3**	Proportion/Type and grading of aggregates shall be made by trial in such a way so as to obtain densest possible concrete. All ingredients of the concrete should be used by mass only.	All ingredients of concrete shall be used by mass except water and chemical admixtures which may be by volume.
19	**10.2.5**	It is important to maintain the water-cement ratio constant at its correct value. To this end, determination of moisture contents in both fine and coarse aggregates shall be made as frequently as possible, the frequency for a given job being determined by the engineer-in-charge according to weather conditions. The amount-of the added water shall be adjusted to compensate for any observed variations in the moisture contents. For the determination of moisture content in the aggregates, IS 2386 (Part 3) may be referred to. To allow for the variation in mass of aggregate due to variation in their moisture content, suitable adjustments in the masses of aggregates shall also be made. In the absence of -exact data, only in the case of nominal mixes, the amount of surface water may be estimated from the values given in Table 10.	It is important to maintain the water-cement ratio constant at its correct value. To this end, determination of moisture contents in both fine and coarse aggregates shall be made as frequently as possible, the frequency for a given job being determined by the engineer-in-charge according to weather conditions. The amount-of the added water shall be adjusted to compensate for any observed variations in the moisture contents. For the determination of moisture content in the aggregates, IS 2386 (Part 3) may be referred to. Where batching plants are used, it is recommended to determine moisture content by moisture probes fitted to the batching plants. To allow for the variation in mass of aggregate due to variation in their moisture content, suitable adjustments in the masses of aggregates shall also be made. In the absence of -exact data, only in the case of nominal mixes, the amount of surface water may be estimated from the values given in Table 10.
20	**10.3** Mixing	Concrete shall be mixed in a mechanical mixer. The mixer should comply with IS 1791 and IS 12119. The mixers shall be fitted with water measuring (metering) devices. The mixing shall be continued until there is a uniform distribution of the materials and the mass is uniform in colour and consistency. If there is segregation after unloading from the mixer, the concrete should be remixed.	Concrete shall be mixed in mechanical mixer (see also IS 1791 and IS 12119). It shall be ensured that stationary or central mixers and truck mixers shall comply with the performance criteria of mixing efficiency as per IS 4634. Mixing efficiency test shall be performed at least once in a year. The mixers shall be fitted with water measuring (metering) devices. The mixing shall be continued until there is a uniform distribution of the materials and the mass is uniform in colour and consistency. If there is segregation after unloading from the mixer, the concrete should be remixed.
21.	**10.3.1**	For guidance, the mixing time shall be at least 2 min. For other types of more efficient mixers, manufacturers' recommendations shall be followed; for hydrophobic cement it may be decided by the engineer-in-charge.	As a guidance, the mixing time shall be at least 2min for conventional free fall (drum) batch type concrete mixers. For other types of more efficient mixers, manufacturers' recommendations shall be followed.

<table>
<tr>
<td>22</td>
<td>10.3.3</td>
<td>Dosages of retarders, plasticisers and superplasticisers shall be restricted to 0.5, 1.0 and 2.0 percent respectively by weight of cementations' materials and unless a higher value is agreed upon between the manufacturer and the constructor based on performance test.</td>
<td>Dosages of retarders, plasticisers and superplasticisers shall be restricted to 0.5, 1.0 and 2.0 percent respectively by mass of cementitious materials; however, the dosages of polycarboxylate based admixtures shall not exceed 1.0percent. A higher value of above admixtures may be used, if agreed upon between the manufacturer and the constructor based on performance test relating to workability, setting time and early age strength.</td>
</tr>
<tr>
<td>23</td>
<td>11.1 General</td>
<td>The formwork shall be designed and constructed so as to remain sufficiently rigid during placing and compaction of concrete, and shall be such as to prevent loss of slurry from the concrete. For further details regarding design, detailing, etc, reference may be made to IS 14687. The tolerances on the shapes, lines and dimensions shown in the drawing shall be within the limits given below:
<table>
<tr><td>a)</td><td>Deviations from specified dimensions of cross-section of columns and beams</td><td>+12 to –6 mm</td></tr>
<tr><td>b)</td><td>Deviation from dimensions of footings</td><td></td></tr>
<tr><td></td><td>1) Dimensions in plan</td><td>+50 to –12 mm</td></tr>
<tr><td></td><td>2)Eccentricity</td><td>0.01 times the widths of the footing in the direction of deviation but not more than 50mm</td></tr>
<tr><td></td><td>3) Thickness</td><td>± 0.05 times the specified thickness</td></tr>
</table>
</td>
<td>
<table>
<tr><td>(a)</td><td>Deviation from specified dimensions of cross-section of columns and beams</td><td>+10 to –5 mm</td></tr>
<tr><td>(b)</td><td>Deviation from dimensions of footings</td><td></td></tr>
<tr><td></td><td>1) Dimensions in plan</td><td>+50 to –10 mm</td></tr>
<tr><td></td><td>2) Eccentricity</td><td>0.02 times the width of the footing in the direction of deviation but not more than 50 mm</td></tr>
<tr><td></td><td>3) Thickness</td><td>+50 to –10 mm or ±0.05 times the specified thickness, whichever is less</td></tr>
</table>
In this amendment, The tolerances on shapes, lines and dimensions are revised.
</td>
</tr>
<tr>
<td>24</td>
<td>13.4 Construction Joints and Cold Joints</td>
<td>Joints are a common source of weakness and, therefore, it is desirable to avoid them. If this is not possible, their number shall be minimized. Concreting shall be carried out continuously up to construction joints, the position and arrangement of which shall be indicated by the designer. Construction joints should comply with IS 11817.</td>
<td>Joints are a common source of weakness and, therefore, it is desirable to avoid them. If this is not possible, their number shall be minimized. Concreting shall be carried out continuously up to construction joints, the position and arrangement of which shall be indicated by the designer.</td>
</tr>
<tr>
<td>25</td>
<td>Table 11</td>
<td>Characteristic Compressive Strength Compliance Requirement
(Clases 16.1 and 16.3)
<table>
<tr><th>Specified Grade (1)</th><th>Mean of the group of 4 Non-overlapping consecutive test result in N/mm^2 (2)</th><th>Individual test result in N/mm^2 (3)</th></tr>
</table>
</td>
<td>Characteristic Compressive Strength Compliance Requirement
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<table>
<tr><th>Specified Grade (1)</th><th>Mean of the group of 4 Non-overlapping consecutive test result in N/mm^2 (2)</th><th>Individual test result in N/mm^2 (3)</th></tr>
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</tr>
</table>

		M15	≥ f_{ck} + 0.825 × established standard deviation (rounded off to nearest 0.5 N/mm^2) or f_{ck} + 3 N/mm^2, whichever is greater	≥ f_{ck} – 3 N/mm^2
		M20 or above	≥ f_{ck} + 0.825 × established standard deviation (rounded off to nearest 0.5 N/mm^2) or f_{ck} + 4 N/mm^2, whichever is greater	≥ f_{ck} – 4 N/mm^2 IES-2009
		NOTE– In the absence of established value of standard deviation the values given in Table 8 may be assumed, and attempt should be made to obtain results of 30 samples as early as possible to establish the value of standard deviation.		

		M15	≥ f_{ck} + 0.825 × established standard deviation (rounded off to nearest 0.5 N/mm^2) or f_{ck} + 3 N/mm^2, whichever is greater	≥ f_{ck} – 3 N/mm^2
		M20 or above	≥ f_{ck} + 0.825 × established standard deviation (rounded off to nearest 0.5 N/mm^2) or f_{ck} + 4 N/mm^2, whichever is greater	≥ f_{ck} – 4 N/mm^2 IES-2009
		Note –: (1). In the absence of established value of standard deviation, the value given in Table 8 may be assumed, and attempt should be made to abstain results of 30 samples as early as possible to establish the value of standard deviation. (2). For concrete of quantity up to 30 m^3 (where the member of samples to be taken is less than four as per the frequency of sampling given in 15.2.2) the mean of test results of all such samples shall be f_{ck} + 4N/mm^2 minimum.		

26	**24.4.1 Restrained Slab with Unequal Conditions at Adjacent Panels**	In some cases the support moments calculated from Table 26 for adjacent panels may differ significantly. The following procedure may be adopted to adjust them. a) Calculate the sum of moments at midspan and supports (neglecting signs).	In some cases the support moments calculated from Table 26 for adjacent panels may differ significantly. The following procedure may be adopted to adjust them. a) Calculate the sum of the midspan moments and the average of the support moments (neglecting signs) for each panel.
27	**26.2.1 Development Length of Bars - NOTES –** ***Note 3 added***	Only 2 Note items mentioned.	3) For plain cement concrete of M15grade with nominal reinforcement, the design bond stress may be taken as 1.0 N/mm^2.
28	**26.2.1.1 Design bond stress in limit state method for plain bars in tension shall be as below:**	For deformed bars conforming to IS 1786 these values shall be increased by 60 percent. For bars in compression, the values of bond stress for bars in tension shall be increased-by 25 percent.	For deformed bars conforming to IS 1786 these values shall be increased by 60 percent. For bars in compression, the values of bond stress for bars in tension shall be increased-by 25 percent. For fusion bonded epoxy coated deformed bars, design bond stress values shall be taken as 80 percent of the values given in the above table.

<table>
<tr><td>29</td><td>35.3.2 Cracking – 3rd para</td><td>The surface width of the cracks should not, in general, exceed 0.3 mm in members where cracking is not harmful and does not have any serious adverse effects upon the preservation of reinforcing steel nor upon the durability of the structures. In members where cracking in the tensile zone is harmful either because they are exposed to the effects of the weather or continuously exposed to moisture or in contact soil or ground water, an upper limit of 0.2 mm is suggested for the maximum width of cracks. For particularly aggressive environment, such as the ‘severe’ category in Table 3, the assessed surface width of cracks should not in general, exceed 0.1 mm.</td><td>The surface width of the cracks should not, in general, exceed 0.3 mm in members where cracking is not harmful and does not have any serious adverse effects upon the preservation of reinforcing steel nor upon the durability of the structures. In members where cracking in the tensile zone is harmful either because they are exposed to the effects of the weather or continuously exposed to moisture or in contact soil or ground water, an upper limit of 0.2 mm is suggested for the maximum width of cracks. For particularly aggressive environment, such as ‘very severe’ and ‘extreme’ categories given in Table 3, the assessed surface width of cracks should not in general, exceed 0.1 mm.</td></tr>
<tr><td>30</td><td>40.5.2 Shear Reinforcement for Sections Close to supports</td><td>If shear reinforcement is required, the total area of this is given by:
$A_s = a_{vb}(v-2d c/av)/0.87f_y \geq 0.4\ a_{vb}/0.87f_y$</td><td>If shear reinforcement is required, the total area of this is given by:
$\Sigma A_{sv} = a_{vb}(v-2d c/av)/0.87f_y \geq 0.4\ a_{vb}/0.87f_y$</td></tr>
<tr><td>31</td><td>B-2.1.1 Direct Tension</td><td>For M50, Tensile stress – 5.2
For M55, Tensile stress – 5.6</td><td>For M50 and above, Tensile stress – 5.2</td></tr>
<tr><td>32</td><td>Table 21</td><td>Permissible stresses in concrete
<table>
<tr><th>Grade of concrete</th><th colspan="2">Permissible stress in compression (N/mm^2)</th><th>Permissible tress In (Average) for plain Bars in Tension</th></tr>
<tr><th></th><th>Bending σ_{cbc}</th><th>Direct σ_{cb}</th><th>τ_{bd}</th></tr>
<tr><td>1</td><td>2</td><td>3</td><td>4</td></tr>
<tr><td>M 10</td><td>3.0</td><td>2.5</td><td></td></tr>
<tr><td>M 15</td><td>5.0</td><td>4.0</td><td>0.6</td></tr>
<tr><td>M 20</td><td>7.0</td><td>5.0</td><td>0.8</td></tr>
<tr><td>M 25</td><td>8.5</td><td>6.0</td><td>0.9</td></tr>
<tr><td>M 30</td><td>10.0</td><td>8.0</td><td>1.0</td></tr>
<tr><td>M 35</td><td>11.5</td><td>9.0</td><td>1.1</td></tr>
<tr><td>M 40</td><td>13.0</td><td>10.0</td><td>1.2</td></tr>
<tr><td>M 45</td><td>14.5</td><td>11.0</td><td>1.3</td></tr>
<tr><td>M 50</td><td>16.0</td><td>12.0</td><td>1.4</td></tr>
</table>
Note–
(1). The values of permissible shear stress in concrete are given in Table 23.
(2). The bond stress given in col 4 Shall be increased by 25 percent for bars in compression.</td><td>Permissible stresses in concrete
<table>
<tr><th>Grade of concrete</th><th colspan="2">Permissible stress in compression (N/mm^2)</th><th>Permissible tress In (Average) for plain Bars in Tension</th></tr>
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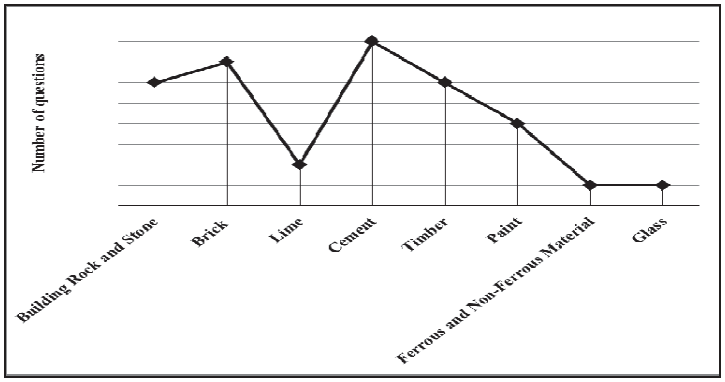
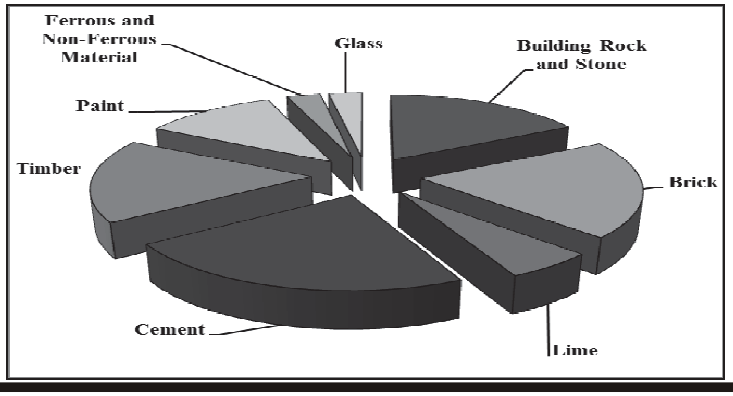
<tr><td>M 40</td><td>13.0</td><td>10.0</td><td>1.2</td></tr>
<tr><td>M 45</td><td>14.5</td><td>11.0</td><td>1.3</td></tr>
<tr><td>M 50</td><td>16.0</td><td>12.0</td><td>1.4</td></tr>
<tr><td>M 55</td><td>18.0</td><td>13.5</td><td>1.5</td></tr>
<tr><td>M 60</td><td>20.0</td><td>15.0</td><td>1.6</td></tr>
</table>
In this amendment, The change to the table is
(a) Substituting the entries against M55
(b) Insertion of a new row for M60</td></tr>
<tr><td>33</td><td>ANNEX E (Clause 25.2) EFFECTIVE LENGTH OF COLUMNS</td><td>E-l : In the absence of more exact analysis, the effective length of columns in framed structures may be obtained from the ratio of effective length to unsupported length l_{ef}/l given in Fig. 26 when relative displacement of the ends of the column is prevented and in Fig. 26 when relative lateral displacement of the -ends is not prevented. In the latter case, it is recommended that the effective length ratio I_{ef} /l may not be taken to be less than 1.2.</td><td>E-l : In the absence of more exact analysis, the effective length of columns in framed structures may be obtained from the ratio of effective length to unsupported length l_{ef}/l given in Fig. 26 when relative displacement of the ends of the column is prevented and in Fig. 27 when relative lateral displacement of the -ends is not prevented. In the latter case, it is recommended that the effective length ratio I_{ef} /l may not be taken to be less than 1.2.</td></tr>
</table>

1 BUILDING MATERIAL

Trend Analysis of Questions topicwise from SSC JE/ ESE/ State PSC & other exam





01.

BUILDING ROCK & STONE

■ Introduction-

- Petrology deals with the study of origin and characteristics of rock.
- Rate of increase of temperature below the earth surface is 15^0-30^0 C/km or 1^0C for every 32 meter.
- The molten mass present at deep depth from the earth surface is known as **magma**. It is the part of upper mantle. When magma comes above the earth surface then it is known as **lava**.
- The major composition of magma is - **Feldspar, Quartz, mica**.

❍ **Rock Forming Minerals-**

UPMRC AM 2023, SSC JE 2018,UPMRC JE 2015

Calcite, Dolomite, Feldspar, Quartz, Mica, Gypsum, Amphibole, olivine.

☞**Gypsum** and **Dolomite** are rock and minerals both.

■ Properties of Mineral-

1. Cleavage-

It is the measure of the capability of minerals to split along certain planes parallel to the crystal faces.

- Types of cleavage seen in minerals are **basal, prismatic, cubic, octahedral**.

2. Hardness-

Hardness is the resistance of a smooth surface against abrasion or scratching. It is measure on Moh's scale.

Minerals	Hardness on Moh's scale	Description
Talc	1	Scratched by the finger nail
Gypsum	2	
Calcite	3	Scratched by knife
Fluorite	4	
Apatite	5	
Feldspar/ Orthoclase	6	Scarcely scratched by knife
Quartz	7	
Topaz	8	Not scratched by knife
Corundum/ Sapphire	9	
Diamond	10	

3. Streak-

UPPSC AE 2020

It is the color of mineral in the powder form.

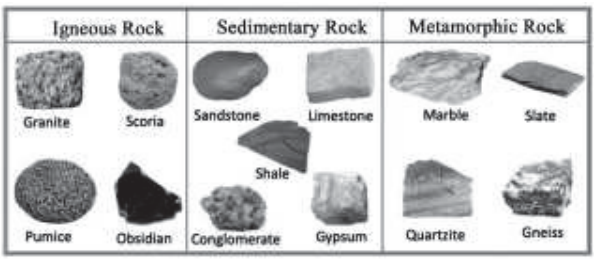
4. Luster-

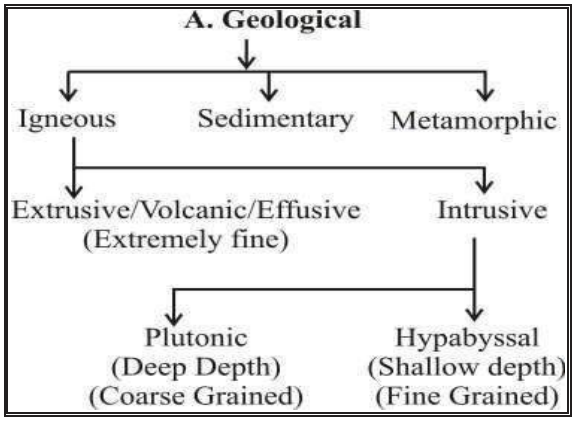
GES 2019

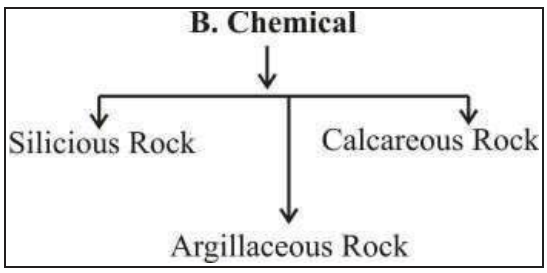
It is the shining of the surface of mineral under reflection of light. It is classified as glassy, greasy, pearly, dull, resinous, silky and metallic.

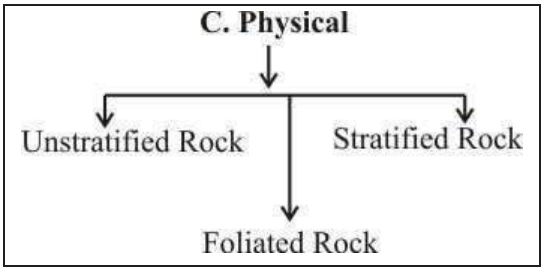
5. Texture- It indicate the coarseness/arrangement of the grains of mineral.

❑ **CLASSIFICATION OF ROCKS-**









■ Geological Classification-

CHB JE 2023, UPRVUNL JE 2022, MHWRD JE 2022, UPPCL JE 2022, SSC JE 2022, NWDA JE 2021

❍ **Igneous/Primary/Unstratified/Eruptive rock-**

SSC JE 2022, DSSSB JE 2019

These rocks are formed by the cooling of molten magma forced up through crack in the earth crust. These rocks have crystalline structure and hard, durable, massive and stronger than other rocks.

Ex. Basalt, Trap, Syenite, Diorite etc.

☛ **Igneous rocks are following two types–**

1. Extrusive/Volcanic/Effusive Rock-

These rocks are formed when the molten magma is cooling and freezing above or at the earth's surface. These rocks have extremely fine grained crystalline structure.

Ex. Basalt, Trap, Andesite, Dolomite, Dacite, Rhyolite, Pumice, Tuff, Scoria etc.

2. Intrusive Rock-

GPSC AE 2018

Due to cooling of magma at a deep/considerable depth from earth's surface.

☛ **These are following two types–**

(i) Plutonic Rock-

UPRVUNL JE 2022, DSSSB JE (Tier-I) 2022 Mizoram PSC 2021, UPMRC JE 2018

These rocks are formed when the molten magma freezing at the deep depth from the earth surface. These rocks have coarse grained crystalline structure.

Ex. Granite, Syenite, Gabbro, Pegmatite, Diorite.

(ii) Hypabyssal Rock-

GPSC AE 2021, DSSSB JE 2019

These rocks are formed when molten magma is solidifies at the shallow depth from the earth surface.

➢ These rocks have fine grained crystalline structure.

Ex. Dolerite, Diorite

❍ **Sedimentary/Aqueous/Stratified Rock-**

MHWRD JE 2022, SSC JE 2022 UKPSC AE 2022, GPSC AE 2021, NWDA JE 2021 BSPHCL JE 2019, DDA JE 2018, SSC JE 2018

These rock are formed by the accumulation or regular deposition of mineral or organic particles at earth surface followed by cementation these rocks have granular structure.

Ex. Sand stone, Lime stone, Gypsum, Laterite, shale, Kankar etc.

❍ **Metamorphic Rock-**

ESE 2022, MHWRD JE 2022, MHADA JE 2022 JSSC JE 2022 DSSSB JE (Tier-I) 2022, RSMSSB JE 2021

Due to high pressure and temperature igneous and sedimentary rocks have changed their physical properties and new types of rock formed. These new types of rock are called metamorphic rock. The resultant mass may have a foliated structure.

Parent Rock	Metamorphic form
Granite, Syenite	Gneiss
Dolerite, Basalt, Laterite	Schist
Dolomite, Lime stone, Marl UKPSC JE 2022 PAPER-II	Marble
Mudstone, Shale	Slate
Sand stone	Quartzite
Gabbro	Serpentine
Bituminous coal	Graphite
Lignite coal	Anthracite

📖 **i).** The texture of igneous rock is depends upon the rate of cooling of magma.

ii). Texture of igneous rock and sedimentary rock is crystalline and granular respectively.

■ Chemical Classification-

DDA JE 2023, UPPCL JE 2022 DSSSB JE (Tier-I) 2022, PSTCL AE 2021

Types of rock	Example
Siliceous Rock- Major constituent is silica (SiO_2). It is very hard and durable.	Granite, Syenite, Basalt, Trap, Sand stone, Quartzite, Gneiss etc.
Calcareous Rock- Major constituent is lime.	Gypsum, Lime stone, Dolomite, Marble etc.
Argillaceous Rock- Major constituent is clay (Al_2O_3). It is hard and brittle in nature.	Shale, Slate, Laterite, Kaolin etc.

■ Physical/Petrological Classification-

1. Stratified Rock-

JSSC JE 2022, RSMSSB JE 2022, NWDA JE 2021 SSC JE 2020, DSSSB JE 2019

These rocks show distinct layers along which the rocks can be split.

Ex. All sedimentary rock like sand stone, lime stone marble, shale, slate etc.

2. Un-stratified Rock-

Do not show any stratification and can't be easily split into thin layers.

Ex. All igneous rocks like granite, syenite, basalt, trap etc.

3. Foliated Rock-

MHWRD JE 2022, NHPC JE 2022, DSSSB JE 2019

These rock can be split up only in a definite direction. Most of the metamorphic rocks have foliated structure, except quartzite, serpentine and marble.

■ On the basis of minerals available-

Types of rock	Example
Monomineralic Rock- These rocks are formed by only one types of mineral.	Gypsum, Marble, Quartzite etc.
Polymineralic Rock- These rocks are formed by two or more than two types of minerals.	Granite, Gneiss, Basalt, Lime stone, Sand stone, Trap, Basalt, Shale, Slate etc.

Key Points

- When heated to 205 ºC, pure gypsum loses its luster and its specific gravity is increased from_____to_____due to the loss of water of crystallization– **2.3 ; 2.95**
- 24 – Hours water absorption of granite should not be greater than– **1%**
- If stone quarrying is done by the blasting method with a length of line of least resistance of 2 m, the rough estimate of gun powder required is– **500 g**
- The metamorphe stone that has porous and spngy structure, can be easily quarried in blocks contains high percentage of iorn–oxide and available in different colours– **Laterite**
- The number of minerals arranged in the Moh's scale of hardness is– **10**
- The aggregates in an example of crystalline surface texture– **Gabbro**
- Specific gravity for most of the building stones lies between– **2.5 to 3.0**

■ On the basis of Percentage of silica available in rock-

1. **Acidic Rock-**
   Silica is greater than 70%- 80%.
   Ex. Granite, Syenite, Rhyolite, Andesite etc.
2. **Basic Rock-**
   Silica is less than 60%.
   Ex. Basalt, Gabbro, Dolomite, Dolerite etc.

❍ **Use of Various Types of stone-**

UKPSC AE 2021, SSC JE 2019

Stone	Use
Granite	Railway ballast, roofing, abutment pier sea walls, and light house. It is costly so not used in general work.
Marble	Ornamental work, monuments, flooring.
Lime Stone	Manufacture of cement.
Slate	Flooring, Roofing for ordinary slab, damp proofing.
Quartzite	Retaining wall, rubble masonry It has best weather resistance.
Basalt	Marine work, Rubble masonry.
Kankar	Manufacture of Hydraulic lime.
Gneiss (metamorphic)	Rough stone masonry work, stone pitching and road metal.
Sand stone	In the form of flag stone, for paving, tile stone for roofing, natural stone for ornamental work and grit for heavy engineering work.

❍ **Stiffness of Rock-**

Descriptive	Modulus of Elasticity (kg/cm^2)
Very Stiff Rock	$8\times10^5 - 16\times10^5$
Stiff Rock	$4\times10^5 - 8\times10^5$
Medium Stiff Rock	$2\times10^5 - 4\times10^5$
Less Stiff Rock	$1\times10^5 - 2\times10^5$
Yielding Rock	$0.5\times10^5 - 1\times10^5$
High Yielding Rock	$0.25\times10^5 - 0.5\times10^5$

■ Quarrying of stone-

❍ **Quarry-**
The place at which stone is obtained is known as quarry.

❍ **Quarrying-**

UPSSC JE 2022, SSC JE 2022

The process under which stone is obtained from rock is known as quarrying.

❍ **Quarry Sap-**
The moisture present in newly quarried stone is called quarry sap.

❖ **Tools used in Quarrying of stone-**

Name of Tools	Use
Priming Needle	To make space for fuse
Jumper	To make hole
Dipper	For making deep hole
Scraping spoon	For cleaning hole
Tamping Rod	For tamping of explosive length = 600mm, dia. = 16mm
Hammer	To penetrate the wedge in rock hole
Wedge	For split the rock slab
Crow bar	To removed the wedge

❖ **Methods of Quarrying-**

UPSSSC JE 2021, PSTCL AE 2021, KPSC AE 2018

Method	Suitability	Example
Wedging	Costly, soft and stratified rock.	Sand stone, Lime stone, Laterite, Marble and Slate etc.
Heating	Those rock whose thermal expansion is very low.	Granite, gneiss etc.

Digging	To get stone at a small scale.	Serpentine, Gypsum, Aterite.
Channeling	Obtaining stone in the form of block.	-
Blasting	To obtain stone at a large scale.	-

■ Blasting-

Boring→Cleaning→Charging→Tamping→Firing

❍ **Quantity of explosive (N)-**

PGCIL DT 2023, UPPCL JE 2022

$$N = [\text{L.L.R.(in m)}]^2 \times 1.5 \text{ (in gm)}$$

$$= \frac{[\text{L.L.R.(in m)}]^2}{0.008} \text{ kg} \quad = \frac{[\text{L.L.R.(in cm)}]^2}{61} \text{ kg}$$

Where, L.L.R.=Length of line of least resistance

❖ **Explosive material used in blasting-**

APSC JE 2018, SSC JE 2017, HPPSC AE 2016

Name of Explosive	Chemical composition
Blasting Gelatin	Nitroglycerin (93%) + Gun-Cotton (7%) **Use-** In deep well, under-ground work, in wet Condition
Gun-Cotton (most powerful)	Cotton with the solution of ($HNO_3 + H_2SO_4$) **Use-** Where demolitions are required.
Dynamite	Nitroglycerine (75%) + Fine sand (25%) **Use-** Both under water and surface blasting
Blasting power /Gun powder	Potassium nitrate (75%) + Charcoal Powder (15%) + Sulphur (10%) **Use-** In quarrying large block
Rock-a-Rock	Potassium chlorate, 79% + Nitrobenzol, 21% **Use-**Best for under water and damp situation blasting.
Cordite	It is gelatinized combination of Nitroglycerine and Nitrocellulose **Use-** Under water
Lithofracteur	Nitroglycerine (33%) + Nitrate of baryta (16%) + Sulphur (26%) + Kieselguhr (22%) charcoal (3%) **Use-** In tunnels

❍ **Detonator-**

It is used to trigger an explosive device.

- Length = 25 mm
- Diameter = 6 mm

■ Dressing of Stone-

NBCC JE 2017

➢ The action which is done on the rough surface of stone to obtain a definite and regular shape are called dressing.

➢ Dressing of stone is done immediately after quarrying and before seasoning to achieve less weight for transportation.

❑ **TYPES OF STONES FINISHING-**

(i) Boasted finishing-

JSSC JE 2022, PGCIL DT 2018, UPRVUNL JE 2016

It is the making non-continuous parallel marks on the surface of stone.

It is done by a tools called boaster.

(ii) Furrowed finishing-

It has beautiful appearance in which sides are sunk up to 20 mm width and the middle portion is projected by 15 mm.

(iii) Polished finish-

It is provided for marbles, granite which are mostly used for floor tiles.

(iv) Reticulated finish-

MPPGCL JE 2023

A margin of 20 mm wide is marked on the sides of surface and irregular sinking type finish is made in the middle area.

(v) Tooled finish-

It is a classic finish which consists parallel continuous marks.

(vi) Scrabbling finish-

The resultant rough surface finish achieved after removing irregular projections on the stone surface by the scrabbling hammer.

(vii) Vermiculated finish-

Sinking in this type of finish is more curved and like worm eaten appearance.

■ Seasoning of stone-

UPMRC JE 2020

The process under which quarry sap are remove from the stone are called seasoning.

➢ Time required for perfect seasoning of stone is- 6 to 12 month.

❖ **Type of stone crusher and its equipment-**

Crusher type	Equipment
Primary	Jaw crusher, Impact and Gyratory crusher and Hammer mill Crusher.
Secondary	Roll crusher, Cone crusher, Hammer mill
Tertiary	Ball mill, Roll mill & Rod-mill

■ Test of Stone-

● Specific Gravity Test-

Aim– To find out the unit weight of stone.

➢ Specific gravity of stone are following two types-

(a) Apparent Specific Gravity (IS : 1124 - 1974)

$$= \frac{\text{Weight of stone/volume of stone}}{\text{Unit weight of water at } 4^0\text{C}}$$

(b) True Specific Gravity (IS : 1122 - 1974)

$$= \frac{\text{Weight of stone particle/volume of stone particle}}{\text{Unit weight of water at } 4^0\text{C}}$$

☛ True specific gravity > Apparent specific gravity

☛ In case of stone, apparent specific gravity is most frequently used which value is 2.4 to 2.8.

Specific gravity of various types of stone-

DDA JE 2023, MP Vyapam Sub. Engg. 2022
RPSC ACF & FRO 2021, DSSSB JE 2019, SJVN JE 2018

Name of Stone	Specific Gravity
Sand Stone	2.65 - 2.95
Marble	2.7 - 2.85
Granite	2.65 - 2.79
Basalt	2.6 - 3.0
Slate	2.72 - 2.89
Laterite	2.0 - 2.2
Lime Stone	2.0 - 2.75
Gneiss	2.5 - 2.7
Quartz	2.65

● Water Absorption Test (IS : 1124 - 1974)

Aim - To find out pore (air voids) in stone mass.

$$w = \frac{W_2 - W_1}{W_1} \times 100$$

W_1 = Weight of oven dry stone

W_2 = Weight of stone after immersing in water for 24 hours.

➢ w % of various types of stone $\nearrow 5\%$ and for hydraulic structure $\nearrow 0.5\%$

UPPCL JE 2018, GPSC AE Class-2 2021

➢ Stone is rejected if w % is > 10%.

❖ **Water absorption of various types of stone (after 24 hours)-**

NHPC JE 2022, TSPSC AEE 2018

Types of Stone	Water absorption (% not greater than
Sand stone, Shale, Lime stone	10
Trap	6
Quartzite	3
Granite, Gneiss, Slate	1

● Durability Test-

Durability is the ability of a material to resist changes in its properties.

➢ For determining durability of stone the crystallization (weathering resistance) test is prescribed by Bureau of Indian Standards.

➢ The durability (Soundness) test is performed to find out the capacity of stone to resist disintegration and decomposition.

➢ Acid test to check weather resistance.

➢ Brard's test for frost resistance.

● Crushing Strength Test [IS : 1121 (Part-I)]

PGCIL DT 2023

Aim- To find out crushing strength of stone.

Apparatus-Compression Testing Machine (CTM).

Size of Specimen-

(i) Cube (50 mm side)

(ii) Cylinder (dia.- 50 mm, height- 50 mm)

Rate of loading- 140 kg/cm^2/min

SJVNL JE 2021

➢ For good building stone compressive strength $\nless 100\text{N/mm}^2$ or 1000 kg/cm^2

PPSC JE 2022, NHPC JE 2022
RIICO Draughtsman 2021

❖ **Compressive Strength of Various Types of Stone-**

TNPSC AE 2019

Stone	Compressive Strength (in M.Pa)
Trap	350 - 380
Gneiss	200 - 370
Basalt	150 - 180
Slate	75 - 200
Dolerite	90 - 150
Syenite	90 - 150
Granite	75 - 120
Sandstone	64
Lime stone	54

Key Points

- The textures of a rock, the arrangement of minerals is in the form of parallel layers– **Foliated**
- The rock exhibits less crushing strength when compared to other mentioned type of rocks– **Laterite**
- The correct unit of measurement for an item of work 'Quarrying of stone or boulders' is– **Cubic metre**

● Transverse Strength Test [IS : 1121 (Part-II)]-

Aim-To find out the transverse strength of stone.

Size of specimen - Beam (200 × 50 × 50 mm)

Effective length of specimen - 150 mm

Transverse strength $R = \frac{3WL}{2bd^3}$ N/mm^2

Where,

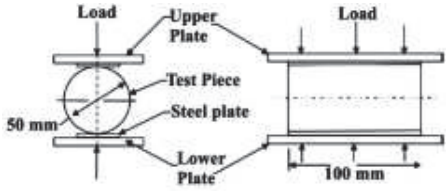
W = Central breaking load in N

L = Length of span in mm

b = Average width of test piece in mm

d = Average depth in mm

- **Tensile Strength Test [IS : 1121 (Part III)]**
  - Cylinder [dia. = 50 mm, H = 100 mm]
  - Diameter to height ratio = 1 : 2



Tensile Strength $S = \frac{2W}{\pi DL}$

Where,

W = Applied load in N

D = Diameter of specimen in mm

L = Length of specimen in mm

- **Shear strength test [IS : 1121 (Part-IV)]-**

This test is performed by Johnson shear tool or Dutton punching shear device.

■ Glance overview of stone test and purpose-

JSSC JE 2022, SJVNL JE 2021, GPSC JE 2020

Type of Test	Determine for
Abrasion Test (By Dory Testing Machine)	Hardness and wearing resistance
Attrition Test (By Deval Testing Machine)	Hardness, Toughness and rate of wearing resistance
Crushing Strength Test (By C.T.M) **(IS : 1121-1974)**	Compressive strength
Smith's Test	Soluble minerals/ Muddy matter. ● It is only qualitative test.
Crystallization Test **(IS : 1126-1974)**	Durability JSSC JE 2022
Hardness Test (Mohs Scale)	Hardness
Impact Test (By Page Impact Machine)	Toughness
Water Absorption Test **(IS 1124-1974)**	% Voids (>5% for good stone)

❖ **Bearing capacity of various types of stone-**

Stone	Max. Bearing Capacity (tone/m^2)
Lime Stone	400
Schist and Shale	300
Clay Shale	100
Compacted sand stone	45
Granite	30 - 35
Loose gravel	25

📖 **Important Point-**

ISRO 2019, GES 2017

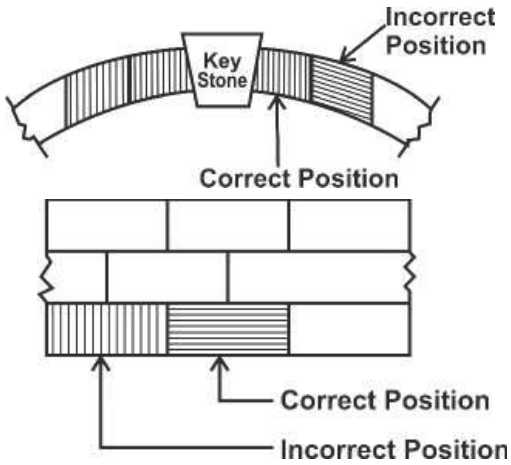
- **Hard Steel ball** are used in Brinell hardness test.
- **Corundum** is a Amery type of stone.
- **Ammonia dynamite** are used for tunneling in soft rock.
- Shingle is a **water bound pebbles.**
- **Chronological order of Hydraulic conductivity** Vesicular basalt > Fractured metamorphic rock > Lime stone > Sand stone.
- Black marble is obtained from Jaipur.
- Hydrolysis is a type of chemical weathering under which granite is convert into clay.

❖ **Stone used in various work-**

UPPSC AE 2013

Hard stone	Used in Rubble masonry ● Cross cut saw is used for cutting
Heavy weight stone	Used in Dam, retaining wall and harbor
Light weight stone	In Arch masonry

- The load which is acting on the surface of stone, must be normal to the natural bed of stone.
- Marble and slate have low electric conductivity.
- Compacted sand stone has good fire resistance.
- Natural bed of stone is radial in arch and perpendicular in wall masonry.



- Colour of sedimentary rock is usually determined by Iron.
- Biotite (rock forming mineral) are also known as black mica.
- Iron slag is used for manufacturing of garlic stone.
- Baryta solution [Barium Hydroxide $\{Ba(OH)_2\}$] is used on stone surface as preservative material.
- Calcium hydroxide is used to protect stones from sulphate attack in Industries.
- Spalling hammer is used for rough dressing of stone.
- Broken bricks or stone chips are also called spall.

Composition of sand stone	Quartz, Lime and Silica.
Composition of granite	Quartz, Feldspar, Mica.

02.

BRICKS

■ Function of Various Ingredients of Brick-

CHB JE 2023, ESE Pre. 2023, DDA JE 2023, MHADA JE 2022, UKPSC JE 2022, UKPSC AE 2022 (Paper-II), CGPSC AE 2022

Ingredients	Properties	Excess
Silica (main ingredient) **(50-60%)**	● Imparts strength and durability ● Prevents shrinkage, cracking and warping ● Retain its uniform shape and make sharp edge of brick	● Brittle and weak on burning and disintegrate the corner of brick (Due to loss of cohesion)
Alumina **(20-30%)**	● Introduce binding property and impart plasticity	● Increase shrinkage and warping of bricks during drying and burning. ● Cracks developed on surface and corner deformed
Lime (mixed in powder form) **(10%)**	● Used as flux and reduces the shrinkage on drying (Reduce melting point) ● Causes silica in clay to melt on burning and thus help to bind it	● Brick over burnt and looses its shape
Iron Oxide **(< 7%)**	● Used as flux ● Provide red colour, strength and hardness	● Provide dark blue or blackish colour
Magnesia **(<1%)**	● Impart yellow colour & prevent shrinkage, ● In burning, it causes the clay to soften at slower rate than does time and reduces warping.	● Decay of brick and give yellowish colour

📖 **Note-**

☛ Liquid limit of brick earth, 25 - 38%.

☛ Plasticity index I_p, 7 - 13%

❍ **Harmful substance in brick earth-**

i. Lime stone or lumps
ii. Gravel, Kankar
iii. Alkalies
iv. Organic matter (Vegetables, roots)
v. Sulphur

Note-

☛ As per the Bureau of Indian Standards, burnt clay bricks are classified in **11 classes** based on their minimum average compressive strength.

■ Vane diagram for manufacturing of brick-

DSSSB AE 2021

1. Site Selection

↓

2. Preparation of brick earth

↓

(i) Unsoiling → **(ii)** Digging→ **(iii)** Weathering→ **(iv)** Blending→ **(v)**Tempering→ Kneading or Pugging

↓

3. Moulding

i. Hand moulding, **ii.** Machine moulding

↓

4. Drying

i. Natural drying **ii.** Artificial drying

↓

5. Burning

i. Pazawah or clamp **ii.** Intermittent kiln
iii. Semi continuous kiln **iv.** Continuous kiln

❍ **Unsoiling-**

The process of removing 20-30 cm thick the top layer of the earth which contain stone, kankar roots and organic substance is termed as unsoiling.

❍ **Digging-**

The process of excavation of soil mass after unsoiling is called digging. The digging operation should be done before rain season.

❍ **Weathering-**

SSC JE 2017

Under this operation the excavated soil is left in exposed weather for some periods due to which it could achieved a good plasticity.

❍ **Blending-**

MH WRD JE 2022, SJVNL 2021, SSC JE 2020

The Process of mixing ingredient which is not present in sufficient quantity in brick earth and to obtain uniform mixture is called blending.

➢ The process of blending should be done at the time of weathering.

❍ **Tempering-**

Under this process required quantity of water is added in soil mass and the whole mass is kneaded as Pressed under the feet of men or cattle and obtain a homogeneous mass having uniform character.

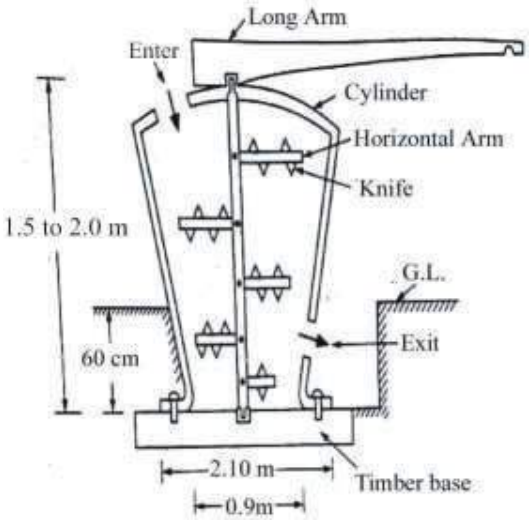
❍ **Kneading or Pugging-**

PGCIL DT 2023, ISRO 2018, SSC JE 2017

Pugmill is used to preparation of brick earth it is called pugging or kneading.

➢ For manufacturing good brick tempering is done in pugmill. This operation is called pugging.

➢ The process of mixing water, clay and other ingredients to make bricks is called kneading.



❍ **Moulding-** JKSSB JE 2022

The process of giving a required shape and size to brick earth in the form of brick is called moulding. It is two types-

(i) Hand moulding (ii) Machine moulding

Steel mould	Wooden mould
Made of steel sheet	It is generally made of Shisham
Sharp surface and corner are achieved	Compared to steel mould is less
Per day brick moulding capacity is less	Its moulding capacity is more

🕮 **Note-**

☛ Steel moulded bricks are good compared to wooden moulded bricks.

☛ Steel moulded brick are used in facing work.

☛ Internal dimension of mould is 10% more than completely burned brick. It is the approximately same as nominal size of brick.

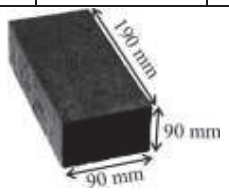
Key Points

- The bricks which are extensively used for basic refractories in furnaces are– **Magnesite bricks**
- According to IS : 1077-1992, non–modular size of the bricks is– **230×110×70 mm**
- **Body bricks** are well burnt bricks occupying central portion of the kiln.

■ Size of various types of bricks-

CHB JE 2023, UPRVUNL JE 2022, UPPCL JE 2022
MH WRD JE 2022, JSSC JE 2022, PPSC JE 2022
DSSSB JE (Tier-I) 2022, UPPCL JE 2020, SSC JE 2020
KPSC JE 2016

Brick Classification	Usual size	Nominal size
Conventional/ Traditional/ user size	$9"\times4\frac{3}{8}"\times2\frac{3}{4}"$	$9"\times4\frac{1}{2}"\times3"$ or (23×11.4×7.6)cm
Standard/ Modular/ Normal size	(19×9×9) cm	(20×10×10)cm



☛ Weight of modular brick is $\simeq 3$ kg.

❍ **Frog-**

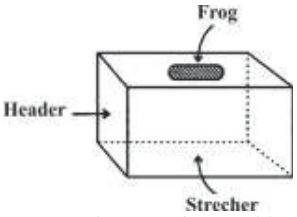
UPPCL JE 2016, UKPSC AE 2022, SSC JE 2022, DDA JE 2023

➢ It is the depression on the top face of the brick made by stock board.

➢ Frog of brick is kept on the top while constructing a wall so that mortar is filled properly in it.

➢ Binding and shear strength of walls are increased due to frog.

➢ Object of frog is forming a key between two course of brick wall.

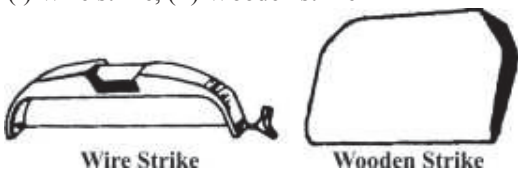


❍ **Stock board-** It is use for making frog on the surface of brick.

❍ **Strike-**

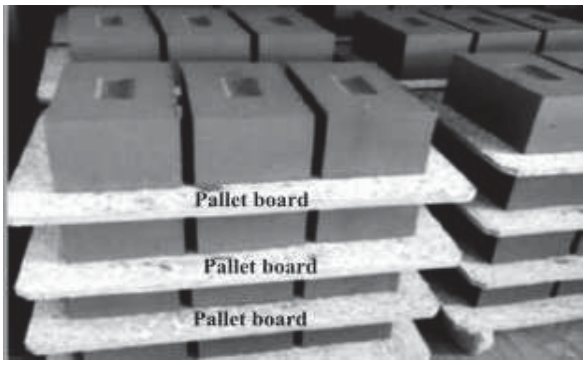
➢ It is use for removing excess soil from the surface of mould. These are two type-

(i) Wire strike, (ii) Wooden strike



❍ **Pallet board–** **BPSC AE 2018**

It is used to carry the moulded brick for drying.



Note- **DFCCIL 2021**

Frog	10 cm × 4 cm × 1 or 2 cm
Stock Board (To make frog)	21 cm × 10 cm × 6 cm
Pallet Board (To dry the brick)	30 cm × 12 cm × 1 cm

Key Points

- Second class bricks are recommended for– **Hidden masonry work**
- The general specification of first class building mentioned below is associated to : "Shall be of first class burnt brick work in lime or cement mortar (1 : 6)"– **Superstrucutres**
- The types of special mortars are used for setting refractory bricks in the furnace linings where the temperature is too high for ordinary mortars– **Fire–shielding mortars**

■ Drying-

The main purpose of drying is to remove the moisture to control the shrinkage and save fuel and time during burning.

➢ Green brick contain about 7 to 30% moisture depending upon the method of manufacture.

Drying of brick is done by following two types

1. **Natural drying-**

Brick should be dried in shaded area, not in sun light.

➢ Number of brick course ⁄ 7 to 8 (in hollow)

➢ Time required for dry = 3 to 7 day (depend on the climate)

2. **Artificial drying-**

This method are use in rainy season or more brick are required in less interval. In this method kiln are used for drying brick.

➢ Strength of Sun dried brick, **15 - 25 (kg/cm^2)**
average 21 kg/cm^2

➢ Moisture content should be available in sun dry brick 3% - 4%.

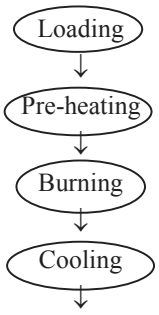
❖ **Strength of hand molded brick-**

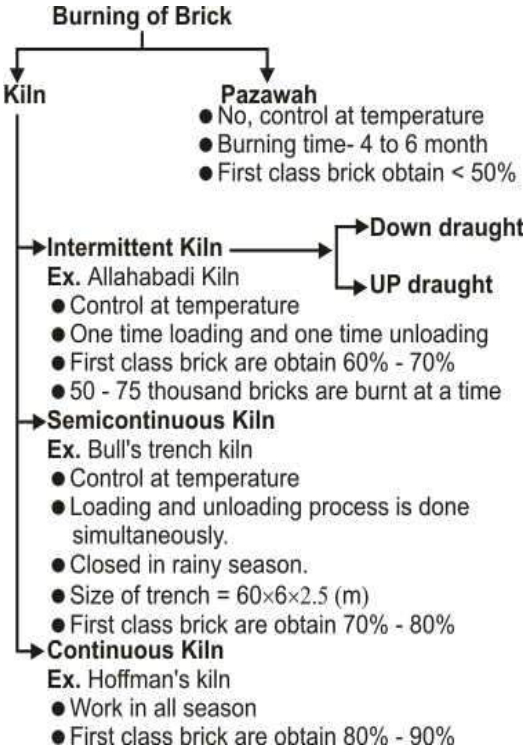
Strength	Value (in kN/m^2)
Crushing strength	60000
Shear strength	6000
Tensile strength	2000

MH WRD JE 2022

■ Burning of bricks

❍ **Steps used for burning of bricks-**

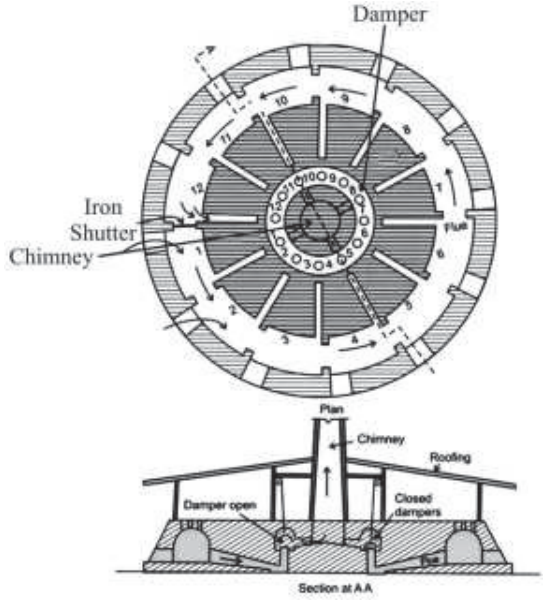




➢ Time required for burning of brick in the kiln is about 24 hours and only 12 days are required for cooling of brick.

❍ **Stage of burning zone-** **KPSC JE 2016**

Dehydration (400 - 650^{0}C)
↓
Oxidation (650 - 900^{0}C)
↓
Vitrification (900 - 1200^{0}C)



Continuous kiln

❑ CLASSIFICATION OF BRICK-

1. On the basis of physical and mechanical Properties

(i) First Class Brick-

GPSC AE 2020-21 & 23 , MHADA JE 2022
PPSC JE 2022, GES 2019, DFCCIL 2018

- Minimum compressive strength ≮ 105 kg/cm^2
- Water absorption after immersed in water for 24 hours ≯ 20%
- Weight – 2.75 – 3 kg

Colour- Uniform deep red or cherry red

❍ **Hardness-**

No impression should be left on the brick when a scratch is made by a finger nail.

- ➢ It should be free from efflorescence.
- ➢ The surface should be smooth and rectangular with parallel, sharp and straight edges and square corner.
- ➢ A metallic sound should come when two bricks are struck against each other.
- ➢ When a horizontal brick is kept on a vertical brick and fall at a 1.5m height the horizontal brick should not be break.

(ii) Second Class Brick-

MHADA JE 2022, DSSSB JE 2019, RPSC 2016

- Minimum compressive strength ≮ 75 kg/cm^2
- Water absorption ≯ 22%
- Colour - Light red
- The impression is left when scratched by finger nail.
- Dull sound formed if two bricks are strucked.

(iii) Third class brick-

- It is also known as under burned brick.
- Minimum compressive strength ≮ 35 kg/cm^2
- Water absorption < 25%
- Colour - Yellowish

(iv) Fourth class or jhama brick- GPSC AE 2021

- Due to over burned its shape and size are changed.
- Compressive strength = 300 – 350 kg/cm^2
- Water absorption = 8 – 10%

➪ **Colour** - Dark blue

➪ **Use** : Soling coat of road and foundation.

🕮 **Note-**

☛ According to IS code : bricks having compressive strength < 35 kg/cm^2 should not be used.

2. On the basis of grade (IS : 1071 - 1971)-

NBCC JE 2017, DFCCIL JE 2016

Grade of brick	Min. Compressive strength (kg/cm^2) ≮
Grade AA	140
Grade A	105
Grade B	70
Grade C	35

3. On the basis of compressive strength-

UP Awash Vikash Parishad 2022

Class	Average Compressive Strength not less than (kg/cm^2)
35	350
40	300
25	250
20	200
17.5	175
15	150
12.5	125
10	100
7.5	75
5	50
3.5	35

❑ SPECIAL TYPES OF BRICKS-

MPPGCL JE 2023, GPSC AE 2022
DSSSB JE 2019, NBCC JE 2018

1. Refractory brick/Fire resistance brick-

These brick are capable to resist very high temperature up to 1500^{0}C without melting or softening. RPSC ACF & FRD 2021

- ➢ Lime quantity kept less so that brick burnt at high temperature of 1700 - 1800^{0}C.
- ➢ The minimum average compressive strength- 32.5 MPa.
- ➢ Water absorption- 4 - 10%

Colour- Whitish yellow or light brown.

Use- Furnace lining, hollow tiles etc.

❍ **Refractory bricks are following three types-**

UPPCL JE 2022, CGPSC AE 2021

A. Acid refractory brick-

Ingredient: 95 - 97% silica + 1 - 2% lime

Use: Where acidic slag are formed.

B. Basic refractory brick-

These are use where basic slag are made. These are two types-

a. Magnesia refractory brick-

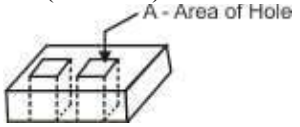
RSMSSB JE 2022

Ingredient- 70% magnesium oxide (MgO) + 30% silica and alumina

b. Dolomite refractory brick-
In these brick is carbonate of calcium and magnesium [$CaMg(CO_3)_2$] are used as raw material
Use : In shaft and rotary kilns, which are use for production of lime and cement.

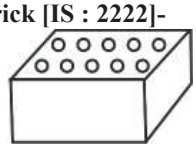
C. Neutral refractory brick-
Ingredient of these brick are bauxite, silica and iron oxide. It is use where acidic or basic slag are made.

2. Hollow brick (IS : 3952)- SSC JE 2017



- Maximum hollow $\not>$ 50% of total plan area.
- It is use for making sound proof and heat resistance wall.

3. Perforated Brick [IS : 2222]-



- Total hollow area $\not>$ 30 - 40% of total plan area.

Use- Covering wall sound proof and heat insulating wall construction.

Compressive strength	$\not<$ 7N / mm^2
Water absorption	$\not>$ 15%
Efflorescence	$\not>$ 10%
Warpage	$\not>$ 3%

4. Over-burnt brick-
In over burnt brick a soft molten mass is produced and the brick loose their shape.

5. Under burnt brick-
NHPC JE 2022

When bricks are not burnt to cause complete vitrification, the clay is not softened because of insufficient heat and the pores are not closed. These brick have higher degree of water absorption and less compressive strength.

❖ **Sample required for various brick test-**

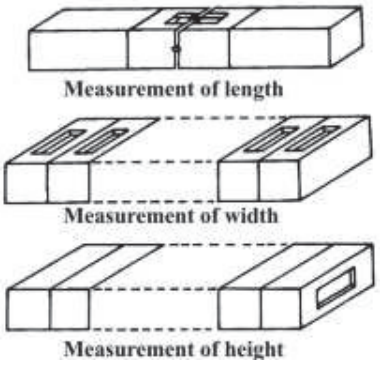
Bricks Test	I.S. Code	No. of Sample
Compressive strength test	3495-Part I	6
Water absorption test	3495-Part II	5
Efflorescence test	3495-Part III	–
Warpage test	3495-Part IV	10
Dimension test	1077	20

Key Points

- .....are caused in bricks by entrapped air the void of clay– **Lamination**
- ..... is comparatively finer and possesses better adhesive and cohesive properties– **Clay**
- Refractory bricks are specially manufactured to– **withstand high temperature**
- The most important purpose of frog in a brick is to– **Form keyed joint between bricks and mortar**

❑ **TEST OF BRICK-**

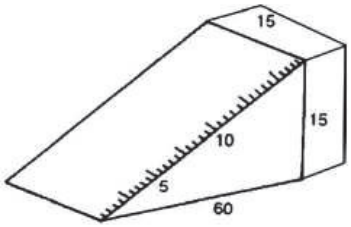
1. Dimension Test (IS : 1077)-
RSMSSB JE 2016, UPSSSC JE 2015



❖ **For modular size brick-**

For 20 brick	Dimension (cm)	Tolerance (mm)
Length	380	± 80
Width	180	± 40
Height-		
(i) 9 cm	180	± 40
(ii) 4 cm	80	± 20

2. Warpage Test [IS : 3495 (Part-IV)]-
Warpage of brick is measured with half of a flat steel or glass surface and measuring ruler graduated in 0.5mm division or wedge of steel 60×15×15 mm.



3. Efflorescence Test [IS : 3495 (Part III)]-
APSC JE 2020, DSSSB JE 2019, ESE 2016

Aim- To find the alkali matter of soluble salts present in brick.

- Efflorescence is characterized by the white patches on the surface of the brick.
- Depth of water in container = 25 mm

Percent area covered by white Patches	Efflorescence
0%	Nil
0% – 10%	Slight
10% – 50%	Moderate
>50% [But white patches does not change in powder form]	Heavy/severe
>50% [White patches changes into powder form]	Serious

- The efflorescence to be not more than moderate (10 – 50%) for class 12.5 and not more than slight (< 10%) for higher class.
- Brick should be rejected if white powder available on the brick surface is > 50% of total area.

4. **Compressive Strength Test [IS : 3495(Part-I)]-**
This test is performed by compression testing machine

- Rate of loading = 140 kg/cm^2/minute
- Proportion of mortar to fill the frogs- 1:3

5. **Water Absorption Test [IS : 3495(Part-II)]-**
Aim- To find out the existence of pores in brick.

$$w = \frac{W_2 - W_1}{W_1} \times 100$$

Where,

w = Water absorption (in percent)

W_1 = Weight of oven dry $(105 \pm 5^0 C)$ brick

W_2 = Weight of brick after immersion it in water for 24 hours.

- If w < 7% Then brick is high resistance to damage by freezing.

- **Field test of brick earth-**
  1. Consistency test
  2. Moulding test
  3. Deformation and shrinkage test
  4. Strength test
  5. Testing, nature of soil ground

DEFECT OF BRICKS

1. **Under burnt-**
Caused due to insufficient heat and are not able to carry the desire load.
2. **Over burnt-**
It occurs due to extremely high heat and not suitable for construction work.
3. **Lime bursting problem-**
A common defect of bricks/tiles which is caused by the hydration of quick lime particles.

- By mixing common salt in black cotton soils, lime bursting can be prevented, 0.5% Sodium chloride is sufficient.
- Put all the bricks in water just after they removed from the kiln, this process is called **docking.**

4. **Efflorescence-** CIL MT 2020
Presence of drying grey or white powder patches on the brick surface is known as efflorescence.

- This defect is caused because of alkalis present in bricks.

5. **Chuffs-**
DSSSB JE 2019, MPSE 2018, SSC JE 2017
The deformation of the shape of bricks caused by the rain water falling on hot brick is known as chuffs.

6. **Blister-**
Broken blister are generally caused on the surface of sewer pipes and drain tile due to air imprisoned during their molding.
7. **Lamination-**
It is the thin lamina produces on the brick faces.
Cause-Entrapped air in clay voids.
8. **Bloating-**

This defect observed as spongy swollen mass over the surface of burnt brick. It is caused due to the presence of excess carbonaceous matter and sulphur in brick clay.
9. **Checks or Cracks-**
This defect may be because of lumps of lime or excess of water.
10. **Black core-**
If bituminous matter or carbon is present in brick earth and they are not completely removed by oxidation, the brick result in black core. Prime cause of brick black core is improper burning.
11. **Spots-**
Due to presence of iron sulphide in brick earth, the dark spots remains on the brick surface.

- Unsuitable for exposed masonry work.

12. **Brick spalling-**
It is the irregular portion of the brick away or fall off from the surface.
Cause-Heating of water inside brick.

- **IS : 3102** $\rightarrow$ Classification of burnt clay solid brick.
- **Heavy duty burnt clay brick (IS : 2180)-**
MP Vyapam 2022, ESE 2017
These are similar to burnt clay brick and of the same size but with high compressive strength.
- **Burnt clay paving brick (IS : 3585)-**
These are used in drive ways and for land scaping parks and garden.
Compressive Strength $\not< 40\,N/mm^2$
Water absorption $\not> 5\%$
- **Soling brick [IS : 5779]-**
  - These are used for soling of roads.
  - Compressive strength $\not< 5\,N/mm^2$
  - Water absorption $\not> 20\%$
  - Efflorescence $\not> 10\%$

TILES

The clay product which thickness is less than 40mm is known as tiles.

- Burning of tiles is same as brick burning but some times tiles or clay products are burnt in two times-
- Ist is at 600 - 700^{0}C is called biscuting and IInd is at 900 -1100^{0}C, after dipping the tiles/clay product in the solution of desired colour.

❑ SPECIAL TYPES OF CLAY PRODUCT-

❍ Stoneware-

UPPCL JE 2016; 2022, UKPSC AE 2022, SSC JE 2022

It is made from refractory clay mixed with crushed pottery, stone and sand, burnt at high temperature and cooled slowly. Stoneware consists of about 75% silica and 25% alumina. Iron oxide is added to give colour

Ex.–Domestic sewer pipe, wash basin, water closet, drains pipe and fittings.

❍ Earthenware-

GPSC AE Class-2 2021

These are made by burning ordinary clay at low temperature and cooling slowly. Glazed earthenware becomes resistant to weathering action.

Ex.- Faience

❍ Majolica-

It is Italian earthenware coated with opaque white enamel, ornamented with metallic colour.

- Manufactured from low heat clays to which up to 20% calcium carbonate added in the form of chalk.

Use- Doorways, window casing and facing tiles.

❍ Fire Clay-

These are pure hydrated silicates of alumina and contain a large proportion of silica (55-75%), alumina (20-35%), Iron oxide (2-5%) with about 1% of lime, magnesia and alkalis.

- It is capable of resisting very high temperatures up to 1700^{0}C, without melting or softening and resist spalling. UPPCL JE 2022

Use- For manufacturing fire bricks used in furnace lining, hollow tiles and crucibles.

❍ Terracotta-

UKPSC AE 2022 (Paper-II)

Clay is mixed with powdered glasses, pottery and sand ground to fine powder and pugged several times till it gets uniform and soft for moulding.

- Terracotta is refractory clay product and is used in ornamental parts of building.
- The clay used should have sufficient iron oxide and alkaline matters.
- It is cheap and impervious.
- Muffle furnace are use for burning of terracotta product.

❍ Porcelain- UPSSC JE 2022 GES 2017

A high grade ceramic ware having white colour, zero water absorption and glazed surface.

- Porcelain is fine earthenware which is white, thin and semi-transparent.
- It is used for manufacturing sanitary wares containers and crucibles, reactor chambers and electric insulators.

❍ Glazing-

Glazing is a process of providing a glassy or impervious layer on the surface of clay product or ceramics.

- The glazing layer is fused to a ceramics body by burning at a high temperature.
- Thickness of glazing is 0.1 to 0.2 mm.

■ Classification of glazing-

MPSE 2018

(i) Transparent Glazing-

Clay product is coated with NaCl solution and burned at high temperature (1000^{0}C - 1200^{0}C)

(ii) Opaque Glazing-

- This is also known as enameling.
- Borax, kaolin, chalk and colouring matter are grinding and mixing water and make solution which is called slip.
- The clay product is dipped in slip and burnt in kiln. Due to high temperature surface is change into impervious layer.

(iii) Lead Glazing-

Clay product is immersed in the mix of Lead and Tin oxides. The particles of Lead and Tin adhere the surface of clay products. This method of glazing is used for items of interior clay which cannot with stand high temperature required for salt glazing.

Key Point

- Unit weight of broken brick – **14.2 kN/m^3**
- Stone chips or Broken brick are also known as- **Spall**
- Specific gravity of machine moulded brick– **2**
- Specific gravity of hand moulded brick– **1.6 - 1.7**
- The No. of Compartment in Hoffman's Kiln is- **8 to 24.**
- The edge formed by the intersection of plane surfaces of brick are called- **Arrises**
- The brick made from Olivine rock to which magnesia added in the manufacturing process are called– **Forsterite brick**
- Density of brick in g/cm^2 – **1.8 to 2.5**
- The water absorption of heavy duty burnt clay bricks having compressive strength greater than 40 N/mm^2 is– **10%**
- The formation of dull patches occurs on the finished and polished surface is called– **Bloom**
- Testing of vitrified and ceramic tiles is done according to- **IS : 15622 - 2006**
- Classification and characteristics of ceramic tiles- **IS:13712-1993**

03.

LIME

■ Introduction

Lime is a binding material found in the form of lime stone. It is not found in free state in the atmosphere.

➢ Lime is obtained from the calcinations of lime stone.

❖ **Sources of Lime-**

DSSSB JE 2022

Type of Stone	Type of lime
Lime Stone ($CaCO_3$)	Pure Lime
Kankar	Hydraulic Lime
Dolomite ($MgCO_3$)	Magnesia Lime
Gypsum ($CaSO_4.2H_2O$)	Sweet Lime
Shell, Chalk	Pure Lime

❖ **Lime and its chemical formula-**

Name of Lime	Chemical Formula
Lime Stone	Calcium Carbonate [$CaCO_3$]
Lime, Quick lime, Lump lime, White lime, Rich lime, Pure lime	Calcium oxide [CaO]
Slaked lime, Fat lime	Calcium Hydroxide [$Ca(OH)_2$]
Plaster of Paris (P.O.P.)	Calcium Sulphate [$CaSO_4.1/2\ H_2O$]
Gypsum	Calcium Sulphate [$CaSO_4.2H_2O$]

❍ **Calcination-**

UPPCL JE 2022, RSMSSB 2020, SSE 2020, PSPCC 2020

The process under which lime stone is burned at 800^0C to 900^0C to removed CO_2 & moisture is called calcination.

$$\underset{\text{Lime stone}}{CaCO_3} + 42.52\,\text{kcal} \xrightarrow[\text{Calcination}]{800-900^0\,C} \underset{\text{Quick Lime}}{CaO} + CO_2 \uparrow$$

❍ **Slaking of Lime-**

ESE 2023, DSSSB JE 2022

In this process quick lime reacted with water and formed $Ca(OH)_2$.

➢ Volume increases 2 to 2.5 times of its initial volume.

$$\underset{\text{Lime}}{CaO} + \underset{\text{Water}}{H_2O} \xrightarrow{\text{slaking}} \underset{\text{Slaked lime}}{Ca(OH)_2} + \text{Heat}$$

➢ Slaking is an exothermic reaction.

Type of lime	Slaking time
Lump lime, Quick lime, Rich lime, Pure lime, Fat lime, White lime	2 to 3 hrs.
Hydraulic lime, Poor lime, Lean lime	12 to 48 hrs.

❍ **Hardening or setting of lime-**

It depend on the types of lime and its hardening condition. It is three types–

i). Carbonate Hardening
ii). Hydrate hardening
iii). Hydrosilicate hardening

Carbonate hardening-

In this process slaked lime reacts with CO_2 and set & hard. $Ca(OH)_2 + CO_2 \rightarrow CaCO_3 + H_2O + \text{Heat}$

Key Points

- Lime mortar for structural purpose is generally made with– **Hydraulic lime**
- Lime is obtained by burning limestone at a temperature of about– **800ºC**
- The unit of measurement and payment for supply of lime unslaked– **Quintal or cubic metre**
- The product that is formed after the heating of gypsum at 393 K and evaporation of 75% of water content from it– **Plaster of Paris**

■ Various types of lime-

1. Pure lime/Fat lime/White lime/Rich lime-

ESE 2022, DSSSB JE 2022, UPRVUNL JE 2022, ESE 2020, PGCIL DT 2018, GES 2017

It slakes rapidly and its volume increase by 2-2.5 times than its original volume.

➢ These lime contain 95 to 97% calcium carbonate ($CaCO_3$) and quantity of impurity does not increase more than 2 to 3%.

➢ It is manufactured by burning of marble, white chalk, sea shell and coral.

Use-Plastering and white washing.

2. Lump lime-

It is obtain in the form of lump after calcination.

3. Quick lime/Caustic lime-

It is obtained immediate after calcination is called Quick lime.

4. Slaked lime-

The lime whose hydration is completed is called slaked lime.

5. Magnesia lime-

It is manufacture by calcination of dolomite. It contain 20 to 35% magnesia.

● Colour - Reddish

❍ **Types of lime on the basis of Impurities-**

1. Pure lime- Impurities < 5%

2. Impure lime- Impurities >5%

Impure lime is following two types-

(i) Lean lime or Poor lime/Impure lime-

UPRVUNL JE 2022

It consists 80% CaO, less than 5% MgO and clay impurities more than 7% in the form of silica, alumina and iron oxide.

➢ Setting and hardening process is very slow.

➢ It's expansion is less than that of fat lime.

(ii) Hydraulic Lime- JSSC JE 2020, SSC JE 2017

It is capable to setting under water and in damp situation.

MHADA JE 2022

Impurity range- 5 to 30%.

➢ setting time under water- 7 to 30 days.

❖ **Hydraulic lime is classified into further three categories-**

BPSC AE 2022

Item description	Feebly Hydraulic lime	Moderate Hydraulic lime	Eminently Hydraulic Lime
% Impurities	05 to 10%	11 to 20%	21 to 30%
Slacking action	Few minutes	1 or 2 hours	1 day or more
Setting action	3 week or more	1 week or more	1 days or more
Hydraulicity	Feebly	Moderate	Eminently
Use	Used for ordinary masonry work	For superior type of masonry work	Use in very damp places

❖ **Classification of Lime as per BIS : 712-1984-**

DSSSB 2019 & 2022, DSSSB JE (Tier-I 2022) DSSSB JE (TIER-I) 2022

Class of lime	Example	Use
Class A	Eminently Hydraulic lime	Hydraulic structure
Class B	Semi Hydraulic lime	Masonry and in lime concrete
Class C	Pure lime/Fat lime	Plaster work
Class D	Magnesium lime/Dolomite lime	White washing and finishing
Class E	Kankar lime	Masonry mortar
Class F	Siliceous dolomite lime	-

■ Test of lime-

1. Visual Inspection Test-

Class of lime	Colour
Class A	Dirty white
Class B	Light dirty white
Class C	White

➢ Lumps of lime indicates quick lime or unburnt lime.

2. HCl Test/Acid Test-

This test is perform to find out impurities and amount of calcium carbonate.

➢ A teaspoon of powdered lime is taken in the test tube and 10 ml of 50% dilute hydrochloric acid (HCl) is added to it, and heat for few minute.

➢ If bubble is formed during heating it indicate calcinations of lime is not done perfectly.

Class of lime	Description
Class A	Good gel is formed above the layer of inert material.
Class B	A thick gel formed
Class C	Absence of gel

3. Ball Test-

Balls (40 mm size) of stiff lime paste are made and left for 6 hours. After six hours, the balls are immersed in a water basin. If expansion and disintegration of balls is observed, the lime is of type C. Little expansion and numerous crack indicate it to be class B lime. Class A lime will have no adverse effect.

4. Fineness Test [IS : 6932 (Part-IV)]-

This test is perform with the help of sieve.

5. Workability Test [IS : 6932 (Part-VIII)]-

ESE Pre. 2023

To judge the workability of lime sample 1:3 lime sand mortar is prepared and thrown on the brick wall by trowel, if it sticks well, its workability is good.

6. Impurity Test-

A known weight of lime is mixed with water and make solution.

% Weight of residue	Types of lime
< 10 %	Good quality lime
10% - 20%	Fat lime
> 20%	Poor lime

7. Setting time Test-

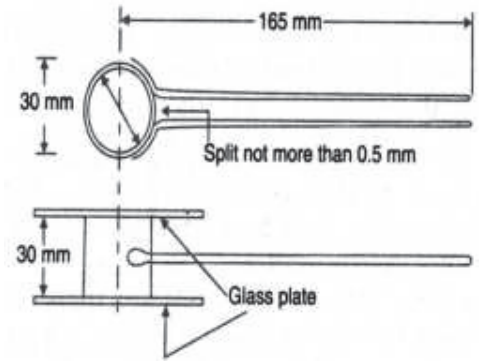
Initial and final setting time of lime is determinate with the help of Vicat's apparatus.

➢ It is the same way as that for cement test.

8. Soundness Test [IS : 6932 (Part-IX)]-

Aim-To find out the quantity of free lime, unsoundness and disintegration property of lime.

➢ This test is conduct with the help of Le-chatelier apparatus.



➢ External diameter of cylinder of Le-chatelier apparatus = 30 mm

➢ The expansion of indicator should not be more than 10mm.

9. Compressive Strength Test [IS : 6932 (Part -II)]-

12 cube of 50mm sides are prepared from standard lime sand mortar (1:3)

➢ 6 Cube are tested after 14 day's and remaining 6 cube are tested after 28 day's with the help of compression testing machine.

➢ Rate of loading- 150 N/min

📖 **Note-**

☛ Carbide lime is a by-Product of manufacturing of acetylene.

☛ Barium plaster is used as final coat for surface of X-Ray room.

☛ Potash- lime glass is also known as Bohemian glass.

❖ **Unit weight of lime-**

Type of lime	Unit weight (kg/m^3)
Unslaked lime	1050
Slaked lime	640
Hardened lime	800

➢ Lime putty is the plastic paste of lime and water.

Class of lime	Modulus of rupture (kg/cm^2)
Class A (Hydraulic lime)	≥ 10.5
Class B (Semi hydraulic lime)	≥ 7

04.

CEMENT

■ Introduction-

MH WRD JE 2022, UPSSSC JE 2022

It is adhesive and cohesive material which are obtained by burning and grinding of calcareous and argillaceous material at very high temperature and grinding the clinker.

- Cement is commonly used as binding material.
- Range of cement particle size- 75-150μ.
- General ingredients of cement-
  (i) Calcareous rocks - 65%.
  (ii) Argillaceous rocks- 35%.

■ Chemical Composition of Cement-

ESE Pre. 2023, PGCIL DT 2023, MH WRD JE 2022
PPSC JE 2022, JSSC JE 2022, SJUNL JE 2021
GPSC AE 2021, WBCS 2019, ISRO 2017, MPSE AE 2017

Oxide/Composition /Average composition	Function
Lime (CaO) 60-65% ≈ 63%	Strength & soundness control, deficiency reduce strength
Silica (SiO_2) 17-25% ≈ 20%	Due to excess reduces strength and slow setting
Alumina (Al_2O_3) 3-8% » 6%	Responsible for quick setting if in excess then lowers strength
Iron oxide(Fe_2O_3) 0.5-6% ≈ 3%	Used as flux
Magnesia (MgO) 0.5- 4% ≈ 1%	Imparts colour & hardness
Gypsum 2-5% ≈ 4%	Used as retarder
Sulphur (SO_3) 1-3% ≈ 1%	Impart soundness
Alkalies 0.2-1% ≈ < 1%	Used as flux & Imparts efflorescence

- The quantity of Sulphur trioxide (SO_3) in OPC cement should not be more than 3%.

■ Function of Ingredients of Cement-

❍ Lime [CaO]-

CHB Jr. Draftsman 2023, SSC JE 2022
RPSC ACF & FRD 2021, SSC JE 2017

- It is major ingredient of cement and act as binder.
- High lime content generally increases the setting time and strength.
- It react with other ingredient and participate the formation of Bogue compounds.
- The presence of excess un-burnt or free lime is harmful since it results in delayed hydration causing expansion (unsoundness) and deterioration of mortar and concrete.
- Deficiency of lime in cement reduces it strength and causes it to set quickly.

❍ Silica (SiO_2)-

ESE 2014

- It is responsible for strength.
- High silica content prolongs the setting time.
- Responsible to make C_3S and C_2S compound.

❍ Alumina [Al_2O_3]-

CGPSC AE 2022, RSMSSB JE 2021

- It is responsible for quick setting.
- In excess quantity causes lower the strength.

❍ Iron Oxide [Fe_2O_3]-

- It is responsible for colour.
- It act as flux.

❍ Magnesia (MgO)-

- It is responsible for colour and hardness.
- If present in excess quantity it causes unsoundness

❍ Sulphur Trioxide (SO_3)-

DDA JE 2023

If SO_3 is present in larger quantities it increases the setting time and causes of unsoundness.

❍ Calcium Sulphate ($CaSO_4 . 2H_2O$)-

It is added in the form of gypsum during grinding of clinker to increase the setting time of cement.

- It acts as a retarder.

❍ Alkalis-

RPSC ACF & FRD 2021

- It causes Efflorescence.
- Alkalis accelerate setting of cement paste.

■ Composition of Cement Clinker-

CHB SDE 2023, JSSC JE 2022, MH WRD JE 2022
JKSSB JE 2021, RSMSSB JE 2021, GPSC AM 2020

- It is also known as Bogue compound and formed during clinkering Process.

NPCIL KAIGA SA 2022, NHPC JE 2022

Name of Compound	Percentage	Other Name	Heat of Hydration	Function
Tri-calcium, Silicate [C_3S]	25 - 50% ≃ 40%	Alite	500 J/g	7 Days hardness and strength
Di-calcium Silicate [C_2S]	25 - 40% ≃ 32%	Belite	260 J/g	Ultimate strength
Tri-calcium Aluminate [C_3A]	5 - 11% ≃ 10.5%	Celite	865 J/g	Flash set
Tetra-calcium Alumino Ferrite [C_4AF]	8 - 14% ≃ 9%	Felite	420 J/g	Poorest cementing value

📖**Note-**

☞ C_3A, C_4AF } Responsible for initial setting time (mainly C_3A)

➢ C_3S, C_2S } Responsible for strength (mainly C_3S)

❍ **Tri-calcium silicate ($3CaO.SiO_2$)-**

RSMSSM JE 2022, KPSC AE 2021, TNPSC 2021

It help (render) the clinker easier to grind, increases resistance to freezing and thawing and develops an early hardness and strength.

➢ If C_3S content raising to beyond the specified limit increase the heat of hydration and solubility of cement in water.

❍ **Di-calcium Silicate ($2CaO.SiO_2$)-**

CHB JE 2023, UKPSC AE 2022, UKPSC AE 2022 GPSC AE 2022, UPSSSC JE 2022, ESE 2021 WBPSC AE 2021

It hydrates and harden slowly and take long time to imparts strength.

➢ It imparts resistance to chemical attack.

➢ It is responsible for ultimate strength.

❍ **Tri-calcium Aluminate [$3CaO.Al_2O_3$]-**

DSSSB JE (Tier-I) 2022, UKPSC JE 2022, SJVN 2019

C_3A is responsible for higher heat of hydration, initial setting, low resistance to sulphate attacks, heat of hydration, and lowers the ultimate strength.

❍ **Tetra-calcium Alumino Ferrite [$4CaO.Al_2O_3.Fe_2O_3$]-**

➢ As increase the C_4AF content the strength reduces slightly.

➢ C_3A is start the hydration but C_4AF has highest rate of hydration.

● **Dormant Period or induction period-**

When water is poured into cement, then cement particle starts reaction with water. This reaction proceeds slowly for 2 to 5 hours and is called dormant period.

● **Order of rate of hydration-**

$$C_4AF > C_3A > C_3S > C_2S$$

● **Order of rate of heat of hydration/hardening-**

RSMSSB JE 2022, UPJN AE 2016

$$C_3A > C_3S > C_4AF > C_2S$$

● **Order of strength-** UJVNL AE 2016

$$C_3S > C_2S > C_3A > C_4AF$$

● **Reaction with water-**

$$C_3A > C_4AF > C_3S > C_2S$$

➢ The above sequence is valid when all compound are taken in equal quantity.

☛ **If quantity of C_3S is increase and C_2S is decrease then-** OPSC 2018

- Increase the rate of hardening.
- Increase the rate of heat of hydration.
- Increase the total heat of hydration.
- Increase 28 day's strength.
- Decrease the ultimate strength.
- Decrease the capability to resist the chemical and Sulphur attack.

☛ **If fineness of cement is increases then-**

- Strength of cement is increases.
- Rate of hydration increases.
- Rate of heat of hydration increases.
- No effect on total heat of hydration.
- No effect on setting time.
- Rate of gain of strength increases.
- Value of shrinkage/contraction increases.

☛ **% Value of C_3A is increases then-**

- Initial setting time is decrease.
- Rate of hydration is increase.
- The value of total heat of hydration is increase.
- There is no effect on strength.

☛ **If % value of C_2S is increases and C_3S is decreases then-** DDA JE 2023

- Increase the ultimate strength.
- The value of 28 day's strength is decreases.
- Increase the capacity to resist chemical attack.
- Value of total heat of hydration is decreases.
- This type of cement is prefer in the construction of hydraulic structure.

■ Hydration of cement-

If water is added to cement a chemical reaction between water and cement starts so that, heat produces, this is called heat of hydration and the process of reaction with water is called hydration of cement.

❍ **Water requirement for hydration of cement-**

RSMSSB JE 2022, SJVNL JE 2021 GPSC AE 2021, PSTCL AE 2021

Bound water - 23% of cement weight

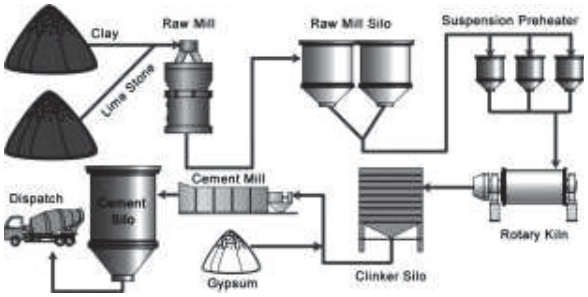
Gel water- 15% of cement weight

So minimum water required for complete hydration is 38% of cement weight.

☛ Chemical reaction of cement with water is an exothermic process.

■ Manufacture of cement-

1. Mixing 2. Burning 3. Grinding



❖ Tools used in Production of Cement-

JSSC JE 2022, JPSC AE 2021

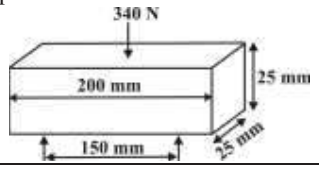
Name of Tools	Use
Gyratory Crushers	To crushed the lime stone and clay in the range of 20 to 50 mm size.
Wash mill	For wet grinding of raw materials. The grinded material which is produced by wash mill is called slurry and it has 40% moisture content.
Silo/storage tank	For the storage of cement.
Rotary kiln Length 90 - 120 m Diameter 1 - 2 m	It is used for burning of slurry. **It has following three chambers-** **(i) Drying Zone** ● Temp. 250^0C to 500^0C ● In this chamber moisture of slurry is evaporate. **(ii) Calcinations Zone–** ● Temp. 700^0C to 1200^0C. ● The calcinations of lime is complete in this chamber. **(iii) Clinker Zone-** ● Temp. 1500^0C to 1700^0C. ● Clinker **(size- 5 to 10mm)** is formed in this chamber. ● Bogue compound are formed in this chamber.
Rotary cooler	**It is used for cooling of clinker.** ● Here clinker cools slowly. ● The strength and quality of cement is depend upon the rate of cooling of clinker.
Ball mill	It is used for coarse grinding of clinker.
Tube mill	It is used for fine grinding of clinker.

- Gypsum is added in cement during the grinding of cement.
- The production cost of cement in dry process is more than that of wet process.
- The dry process is adopted when the raw material are quite hard. This process is slow and production cost is high.
- Quality of cement is good in wet process while poor in dry process.

TEST OF CEMENT

● Field Test-

APPSC AEE 2012

Colour test	The colour of OPC should be greenish grey.
Lump Test	The Presence of lumps in cement indicates that it has absorbed moisture. Cement should be free from presence of any lumps.
Float test	Take a handful of cement and throw it in a bucket filled with water cement particle should sink in water it should not float over the water surface.
Temperature test	Thrust your hand into the cement bag. It must give you a cool Feeling. If hydration reaction takes place inside the bag, it will become warm.
Rubbing test	When cement is rubbed between fingers, there should be smooth feeling.
Smell test	A thin paste of cement with water should feel sticky between the fingers. ● If the cement contains too much-pounded clay and silt as an adulterant, the paste will give and earthy smell.
Strength test	Cement block given below should not fail while loading (340N) is applied in that manner. 

● Lab test/physical test-

1. Fineness Test [IS : 4031 (Part-I)]-

ESE Pre. 2023, UPPCL JE 2022, GPSC AE 2021-22
RPSC ACF & FRD 2021, Mizoram PSC 2021

This is used to check proper grinding which has direct impact on rate of hydration, rate of gain of strength and evolution of heat.

- There are three methods for testing fineness.

(a) Sieve Method-

- In this method particle size of cement is measured
- **Size of sieve-** 90 micron (Sieve No. 9)
- **Sieving time-** 15 minutes
- Weight of cement sample - 100 gm

Result-

The residue should not exceed the limits specified below (after sieving).

Types of cement	Percentage of Residue by weight
Ordinary Portland Cement (OPC)	10
Rapid Hardening Cement (RHC)	5
Portland Puzzolana Cement (PPC)	5

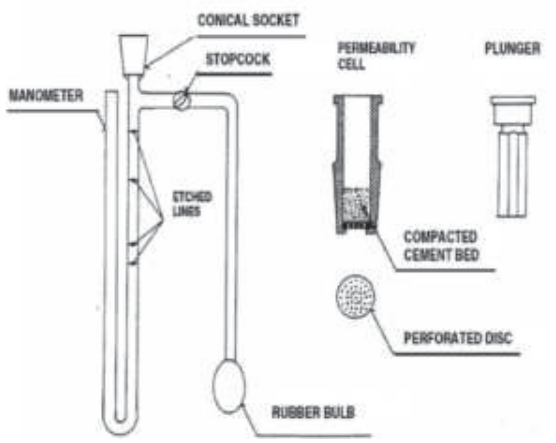
(b) Air Permeability Method or Nurse & Blains Method-

MH WRD JE 2022, PSTCL AE 2021

Fineness is represented in terms of specific surface area (cm^2/gm)

- This test is based on relationship between flow of air through cement bed and surface area of cement particles forming the bed.

NHPC JE 2022, JSSC JE 2022, GPSC AE 2022



Blains air permeability apparatus

- In this method surface area of the cement is measured.

❖ **Minimum specific surface area of cement-**

MHADA JE 2022, JSSC JE 2022
RSMSSB JE 2022, DFCCIL JM 2021

Types of cement	Specific Surface area ≮ cm^2/gm
Ordinary Portland Cement (OPC)	2250
High Alumina Cement (HAC)	2250
Portland Puzzolana Cement (PPC)	3000
Low Heat Cement (LHC)	3200
Rapid Hardening Cement (RHC)	3250
Hydrophobic Cement (H.C.)	3500
Super Sulphate Cement (SSC)	4000

(c) Sedimentation Method or Wagner Turbidity Meter Method-

In this method surface area one gram of cement is measure. Reading are expressed in square cm per gram.

❍ **Factors affecting the fineness of Cement-**

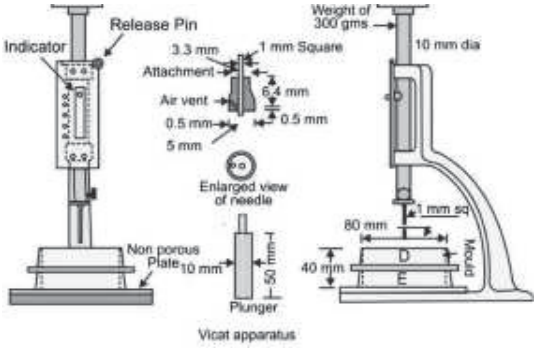
PPSC JE 2022

- Chemical Composition.
- Degree of Calcinations.
- High Iron and silica content in clinker.
- Time of grinding.
- Character of the pulverizing machine.

2. Normal/Standard Consistency Test [IS:5513-1976, IS : 4031 (Part-4 1988)]-

JSSC JE 2022, UPPCL JE 2022, CGPSC AE 2022
MBCC JE 2022, SSC JE 2018

The standard consistency of the cement paste is defined as percentage of water added in 300 g weight of cement which will permit a vicat plunger to penetrate in cement paste to a depth of 33 to 35 mm from the top of the mould or rest from bottom 5 to 7 mm.



JSSC JE 2022, UPRVUNL JE 2022

• Weight of cement sample	300 gm
• Size of mould	Diameter - 80 mm, Height - 40 mm
• Size of plunger	Diameter -10 mm, Height - 50 mm
• Depth of penetration	33 to 35 mm from the top 5 to 7 mm from the bottom.

- The value of normal consistency is depends upon the compound composition and fineness of cement.
- The water requirement for various test of cement depend on the normal consistency of the cement, so this test is perform before than other test of cement.
- Normal consistency of OPC is **- 26 to 33%**

3. Initial and Final Setting Time [IS : 4031 (Part-5), IS : 5513-1976]-

SSC JE 2020-22, JSSC JE 2022, MH WRD JE 2022
MPSC AE 2018, KPSC JE 2017

This test is perform into two parts-

(a) Initial Setting Time (IST) Test-

This test is perform by vicat apparatus with the help of needle.

I.S.T. is the time elapsed between the moment that the water is added to the cement, to the time that paste starts losing its plasticity.

• Quantity of water	0.85 P
• Weight of Cement sample	400 gm
• Weight of movable rod	300 gm
• Diameter of needle	1 mm
• Penetration of needle	33 to 35 mm (from top of the mould)