No.	Question	Response
1	What is responsible for the grey color of cement?	Iron oxide, which is present in some of the raw materials used in the manufacture of cement, is responsible for the grey color of OPC. Reference may also be made to the following for more details: 1. Plumbing and Mechanical Services: A Textbook - Book 3 - Page 124By Arnold H. Masterman, Robert M Boyce 2. Basic Civil Engineering - Page 24 by Satheesh Gopi, Chapter-4,Cement,Section- 4.2
2	What is 'alite', 'belite' for cement chemists ?	Industrial Portland cement clinkers contain tricalcium silicate (C_3S) and beta-calcium silicate (βC_2S), in addition to other solid complexes (mainly tricalcium aluminate and tetra calcium alumino ferrite). These two invariably contain small amounts of magnesium, aluminum, iron, potassium, sodium, and sulfur ions; the impure forms of C_3S and βC_2S are known as *alite* and *belite*, respectively. More information and details are available in any standard text / reference book on cement chemistry or technology, such as those given below: 1. CONCRETE: Microstructure, Properties and Materials (P.K. Mehta, P.J.M. Monteiro, Chapter-6, Hydraulic Cements) 2. Properties of concrete (AM Neville), Chapter 1
3	If a clinker is ground finer, will that change the standard consistency of the cement produced	If the clinker is ground finer, it will increase the surface area of cement. This implies that the area where the hydration reactions will start is higher, and that in turn means that more water will be required to address the water demand for hydration (though not from a pure 'chemistry' viewpoint, by which the amount of water required for hydration is really determined by the amount of cement alone, and that is not being changed). Thus, if the quantity of water is kept fixed, the amount 'available' for workability is likely to be reduced. In other words, to keep the workability constant an increasedamount of water is likely to be required. In a nutshell, finer the cement, more will be the standard consistency. *Note: Standard consistency is essentially defined in terms of the amount of water required to produce a cement paste of a pre-determined consistency.*
4	Draw up a table comparing the specifications for different cement in India and compare it with provisions in some other countries	Reference can be made to the following in drawing up the table. Websites such as *www.indiacements.co.in*, may also be referred to. • IS 269:1989, *Specification for ordinary Portland cement, 33 grade* • IS 8112:1989,*Specification for 43 grade ordinary Portland* • IS 12269:1987,*Specification for 53 grade ordinary Portland* • IS 12330:1988,*Specification for sulphate resisting Portland* • IS 12600:1989,*Specification for low heat Portland cement* • IS 455:1989,*Specification for Portland slag cement* • IS 3466:1988,*Specification for masonry cement* • IS 6909:1990,*Specification for supersulphated cement* • IS 8042:1989,*Specification for white Portland cement* • ASTM C150 (AASHTO M 85), *Specification for Portland Cement*

		• ASTM C595 (AASHTO M 240), *Specification for Blended Hydraulic Cements* • ASTM C1157, *Performance Specification for Hydraulic Cements*
5	Make a list of the air entraining admixtures available in the market and their chemical composition.	Usually the websites of chemical admixture manufacturers and professional bodies gives the details of the different chemical admixtures that are available in the market, along with latest updates. The following websites may be accessed to get the information desired. 1. *http://www.dot.state.mn.us/products/concrete/airentrainingadmixtures.html* 2. *http://www.fosroc.com/Default.aspx* 3. *http://ind.sika.com/*
6	Study the relationship between the different tests for workability of fresh concrete.	Workability of fresh concrete can be measured using several tests – slump, vebe time, slump flow, compaction factor, etc. as discussed in the lecture. As also discussed in the lecture, an increase in workability essentially implies that the concrete become 'easier to work with' – in essence, the concept is the opposite of 'stiffness'. Now, in principle, as the workability of the concrete increases, Vebe time decreases, and an increase can be expected in values of the compaction factor, slump and slump flow. It should be remembered however, that the tests have different ranges of workability over which they can be used to give meaningful result, and, hence only a qualitative comparison as mentioned here can be made. Standard texts in concrete engineering and technology at times give schematic representations of how this relationship can be graphically. Reference may also be made to the following for more details: 1. CONCRETE: Microstructure, Properties and Materials (P.K. Mehta, P.J.M. Monteiro, Chapter-6, Hydraulic Cements) 2. Properties of concrete (AM Neville), Chapter 4 3. Concrete Technology (M.L. Gambhir), Chapter 6
7	Obtain and study the stress-strain curve of concrete and compare it with the 'idealized' curves used in design.	The stress-strain curve is a representation of the(progressive) deformation with increase in applied load, and indeed, experiments in laboratory need to be performed to obtain this for concrete. In the test, the deformation is measured by applying strain gauges and recording the changes (in the strain) as the load is (gradually) increased to failure. Given the heterogeneous nature of the material, in terms of presence of aggregates and the cement paste, and the wide difference in their individual stress-strain behaviors, it is natural that the stress-strain behaviour of the concrete can be looked upon in terms of a combination of the individual behaviours (of the aggregate, which is essentially a rock) and the surrounding 'paste'. The curve is nonlinear and really depends upon several factors including the size of the specimen, rate of loading, condition of the specimen, and so on. As far as idealization is concerned, different codes give different 'idealized'stress-strain curve for concrete. It should also be pointed out that (1) the codes also specify a 'range' of the concrete strength beyond which the 'suggested' curve is not valid and a designer needs to be very careful when using them, and, (2) though such idealized curves can be used for the purpose of design, etc., they are of only limited value in research and academic work. For more information reference may be made to documents such as those given below. 1. *IS 456:2000*, or, 2. *IS:1343-1980*, or,

		3. *http://www.theconcreteportal.com/cons_rel.html*
8	Study more about how the characteristic strength and the target strength of a concrete mix are related based on some of the (international) guidelines.	As very clearly (repeatedly) mentioned in the lecture, the characteristic strength is usually defined as the strength below which not more than a predetermined percentage (usually 5%) of specimen are allowed to fall. On the other hand, the target mean strength is the strength for which the concrete is to be designed (proportioned) in order that the required characteristic strength is achieved. Now, as also explained in the lecture, the latter is higher than the former by an extent that depends upon assumptions made for the distribution of the strength, etc. In the class a normal distribution was assumed, and the effort was to develop an approach where the target strength was expressed in terms the characteristic strength and the expected (or assumed or actual) standard deviation in the strength values and a constant (1.65 corresponds to a permissible failure rate of 5%). Similarly, another approach could be to simply have 'an overdesign factor', wherein the ~~target~~characteristic strength is simply multiplied by this factor to estimate the target mean strength. Of course, the factor itself could be given in relation to the required characteristic strength. The following link may be seen as an additional reference on proportioning of concrete mixes. http://www.ce.memphis.edu/1112/notes/project_2/PCA_manual/Chap09.pdf , page-10
9	Study more about 'no fines' concrete and its applications	An interested reader may begin the search on the subject by going through the following links. 1. http://www.concreteconstruction.net/Images/No%20Fines%20Concrete_tcm45-344300.pdf 2. http://eprints.usq.edu.au/472/1/PaulHARBER-2005.pdf 3. http://archive.org/details/No-finesConcreteARecordOfPermanentStructuresBuiltInTheNewTradition
10	Study more about how the properties of aggregate – both fine and coarse, and cement, affect the relationship of water demand on slump, and the water-cement ratio and compressive strength	Essentially, reference can be made to any text book on concrete materials, engineering or technology. An initial list including, e.g, 1. CONCRETE: Microstructure, Properties and Materials, P. Kumar Mehta, Paulo J. M. Monteiro, Chapter-9, given in the list references and suggested reading. The basic concepts have been covered in the lectures, and the discussion is summarized in the following points: 1. Water content increases as the desired slump increases. Further, for a given slump, the water requirement generally decreases as: (1) the maximum size of a well-graded aggregate is increased; and, (2) the content of angular and rough-textured particles in the aggregate is reduced. It may also be added that the water demand increases as the powder content is increased – which can happen depending upon the choice and characteristics of the sand and cementitious material used. 2. For given strength, water demand increases as cement content increases to keep w/c constant. The following link may be seen as an additional reference on proportioning of concrete mixes. http://www.ce.memphis.edu/1112/notes/project_2/PCA_manual/Chap09.pdf

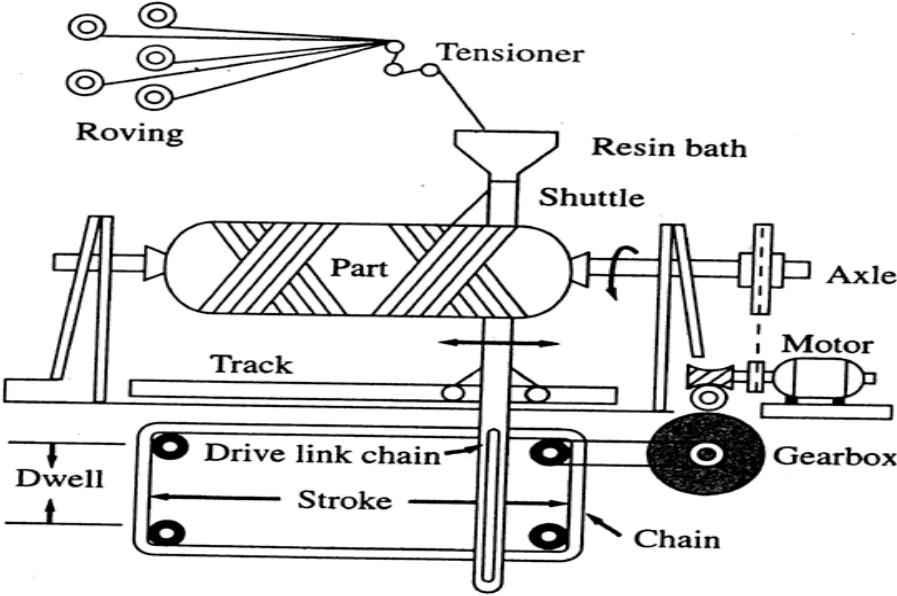|		
11	Indian codes (IS 456, 2000) talks in terms of nominal mixes and design mixes. Find out more about these	It is clearly mentioned in the lecture that, in principle, concrete mixes should be 'designed' and proportioned by weight depending upon (a) the properties of the concrete required, and, (b) the properties of the raw material available. Now, engineering considerations, such as, the volume of concrete involved, urgency of the job, and/or the capability of the contractor carrying out the job, the exercise of carrying out the experiments to actually design the mix, may be determined to be exorbitantly expensive. It is to address such exigencies, that IS 456-2000 provides for use of a nominal mix. In this case, a relative proportion of the different ingredients is 'prescribed', and an agency can use this proportion for certain grades of concrete. Of course, this prescription is available for only a few grades of structural concrete and should be used with utmost caution and discretion. Specific information about the mixes, etc. is available in IS 456, section-2, chapter – 9. The following website may also be seen for additional reading. http://www.engineeringcivil.com/understanding-nominal-and-design-mixes.html
12	Study specifications of concrete which lay down requirements of a maximum water-cement ratio and cement content.	Details of the provision are given in IS 456, section-2, Chapter-8.2 The table essentially 'prescribes' the provisions that will apply to concrete from the point of view of durability. The requirements for the maximum permissible water cement ratio and a minimum cement content, or the use of at least a certain grade of concrete, should be viewed in conjunction with another table that describes the classification ofdifferent exposure conditions. An interested student may also find the discussion in the following paper useful. Misra, S. (2002), Some comments on provisions related to durability in IS 456-2000, *Indian Concrete J*, April
13	How is the workability requirement determined for a reinforced concrete construction?	In the case of reinforced concrete, the material is required to flow around the reinforcing bars without segregation. It has also to be borne in mind that in the process, the aggregates do not form 'arches' between reinforcing bars and prevent the flow of concrete through the bars. Pictures of congested reinforcement have already been shown in the lecture. Thus, qualitatively, it can be argued that as the reinforcement content (say in kgs/m^3) increases, the concrete should be more 'flowing' in order for the above conditions to be satisfied. Further, the 'method and ease of vibration' is another factor that should be kept in mind – in cases when it is easier to carry out the vibration, a lightly lower workability may be permitted, compared to a similar reinforcement content in a situation where vibration is hard to perform. Considerations such as the type of the member and depth of placement (of concrete) could be other relevant considerations. To give a concrete form to this principle, codes sometimes 'prescribe a certain (minimum) workability depending upon the reinforcement content, or, the type of the member, etc. Some examples of such provisions are given in _IS 456, section 2, workability of concrete_ The following link may be used for further information and ready reference. http://faculty.delhi.edu/hultendc/AECT480-Lecture%201-REV.pdf
14	Study more about some other methods of proportioning a concrete mix	Different methods for designing concrete mixes have developed – and only one of them which is essentially based on the principle of absolute volumes being added to fill the required space, has been presented in the lectures. Also, the issue of

		the relationship between say the slump and the unit water content, strength and the water-cement ratio, importance and effect of *s/a* have not been discussed in great detail and have been largely taken as a 'given' for the purpose of designing a concrete mix. An interesting approach to proportioning concrete mixes stems from considerations of maximum packing (density) and optimum moisture content, though this aspect has not been touched upon in the discussion in this module. A more motivated reader may use the following references and links for gaining a greater insight in the process of proportioning concrete mixes. 1. *IS:10262* 2. ACI method of proportioning: http://www.ce.memphis.edu/1112/notes/project_2/beam/ACI_mix_design.pdf 3. BS method of proportioning:http://advancedcivilengineering.blogspot.in/2011/10/concrete-mixed-design-method-bs-method.html
15	Find out more about mercury porosimetry and the equipment used	A more motivated reader may use the following references and links for more information on the subject: 1. http://www.micromeritics.com/pdf/app_articles/mercury_paper.pdf 2. ASTM D4404 – 10: http://enterprise.astm.org/filtrexx40.cgi?+REDLINE_PAGES/D4404.htm 3. BS 7591-1: Porosity and Pore Size Distribution of Materials, Part 1: Method of Evaluation by Mercury Porosimetry 4. http://people.alfred.edu/~giesche/Publications_files/06-1-PPSC%20%28Hg-poro%20practical%29.pdf 5. ftp://ftp.ecn.purdue.edu/olek/PTanikela/To%20Prof.%20Olek/Data/MIP/Mercury%20porosity%20of%20hardened%20cement%20pastes.pdf Powder Surface Area and Porosity by S. Lowell, Joan E. Shields. 1. http://www.upc.edu/pct/en/documents_equipament/d_253_id-734.pdf
16	Collect and analyze data on pore structure in cement concrete with different cements and mineral admixtures	Several research papers deal with the subject and experimental information (data) has been presented therein. A more motivated reader may use the following references and links for more information on the subject. 1. http://ethesis.helsinki.fi/julkaisut/mat/farma/vk/westermarck/useofmer.pdf
17	Study other methods for measurement of pore sizes in cement concrete	Some of the other methods used include ellipsometric porosimetry and thermal porosimetry, and more information about these methods can be found in the following links. *Ellipsometric porosimetry* 1. http://www.freewebs.com/shamiryan/ep_jvst.pdf 2. http://pubs.acs.org/doi/pdfplus/10.1021/bm025541q - does not discuss ellipsometric porosimetry *Thermal Porosimetry* 1. http://scitation.aip.org/getpdf/servlet/GetPDFServlet?filetype=pdf&id=RSINAK000083000005054903000001&idtype=cvips&doi=10.1063/1.4704842&prog=normal

18	What is the Pourbiax diagram	In the context of the present module, the question is largely related to the corrosion susceptibility of metals. Now, the knowledge of only the pH condition of the environment is not sufficient for predicting the form in which an element will exist in natural waters. One must also take into consideration whether the aqueous environment is well aerated (oxidizing) or polluted with organic wastes (reducing). In order to add this variable, the predominance diagram needs to be expanded to include the reduction potential of the environment as well as the pH. This type of predominance diagram is known as a Pourbaix diagram E^o-pH diagram, or pE-pH diagram A more motivated reader may use the following references and links for more information on the subject. 1. http://en.wikipedia.org/wiki/Pourbaix_diagram 2. http://www.wou.edu/las/physci/ch412/pourbaix.htm 3. http://www.doitpoms.ac.uk/tlplib/pourbaix/pourbaix_construction.php 4. http://www.corrosion-doctors.org/Corrosion-Thermodynamics/Potential-pH-diagram-aluminum.htm 5. http://www.corrosion-doctors.org/Corrosion-Thermodynamics/Potential-pH-diagram-iron.htm
19	In steel structures, there is no concrete surrounding the steel. What in this case is the 'electrolyte' in the corrosion process	Most simply speaking, the electrolyte in the case of corrosion in steel in air is moisture absorbed by steel. More information on the subject may be obtained from the following link: 1. http://corrosion-doctors.org/Corrosion-History/Rusting.htm
20	It has been reported that occurrence of corrosion in the submerged part of a marine reinforced concrete structure is much less. What could be the reason for this?	More than chlorides, the corrosion process really needs oxygen to proceed. Now in the case of (constantly) submerged portions of a marine reinforced concrete structure, although chloride ion levels (at the reinforcement level) may far exceed the threshold level required to initiate corrosion of reinforcing steel, the availability of oxygen at the steel-concrete interface, is extremely limited, and this latter factor becomes the controlling factor as far as determining the rate of corrosion is concerned. It should thus be noted that the diffusion of oxygen in fully saturated concrete is very slow and can only support very low corrosion rates. More information on the subject may be obtained from the following link: 1. http://www.concorr.com/PDFfiles/Rep&Protec_Concrete_Seaw.pdf
21	Study available literature on the extent of corrosion in reinforcement that will cause onset of longitudinal cracks	As explained in the classroom instruction, the corrosion products are more voluminous than the parent metal and their formation and deposition on the reinforcing bars subjects the surrounding (cover) concrete to expansive tensile stresses, and concrete being weak in tension cracks leading to the onset of longitudinal cracks. For more information and discussion on the subject, one may use the following links. 1. http://ascelibrary.org/doi/pdf/10.1061/%28ASCE%290733-9445%282005%29131%3A11%281681%29 2. http://www.google.co.in/url?sa=t&rct=j&q=&esrc=s&source=web&cd=1&ved=0CCoQFjAA&url=http%3A%2F%2Fijc.iust.ac.ir%2Fbrowse.php%3Fa_id%3D491%26slc_lang%3Den%26sid%3D1%26ftxt%3D1&ei=eqS1Ue2fFczIrQfZ8oG4DQ&usg=AFQjCNEzaiHO9EtgasQfX5JrVU9MBxdzrw&bvm=bv.47534661,d.bmk&cad=rja

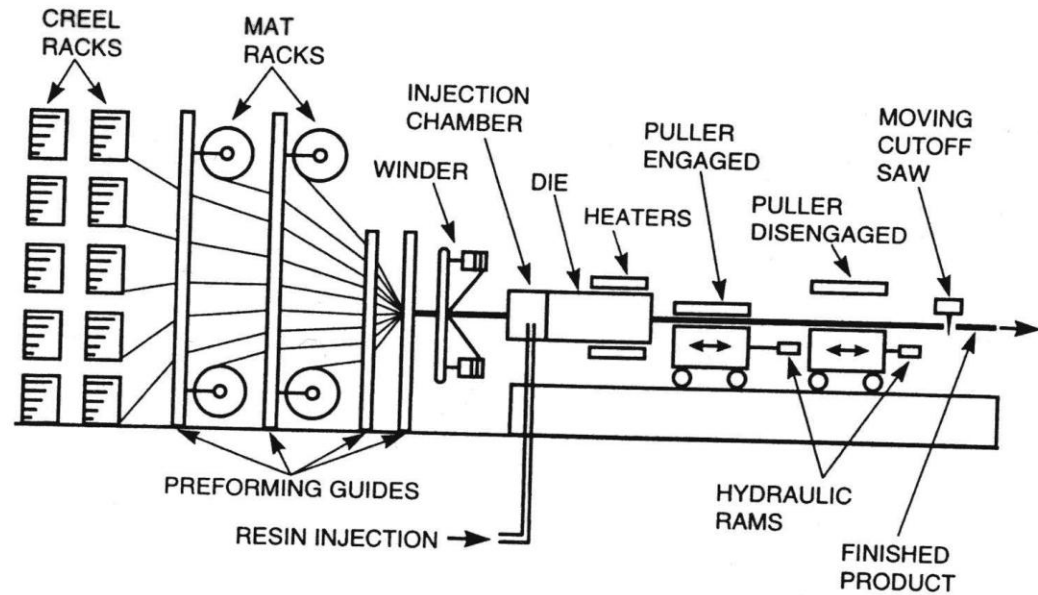| 22	What is Friedel's salt	Formula: $Ca_2Al(OH)_6(Cl, OH)\cdot2\ H_2O$ or $3CaO\cdot Al_2O_3\cdot CaCl_2\cdot10\ H_2O$ Friedel's salt is an anion exchanger mineral belonging to the family of the layered double hydroxides. It has affinity for anions as chloride and iodide and is capable to retain them to a certain extent in its crystallographic structure. The context and relevance of the discussion is in terms of the ability of a cement (and its hydration products) to 'bind' and thereby 'hold down' or 'immobilize' at least a certain part of the chlorides that may be present within concrete. A motivated reader (researcher) may be encouraged to find a clear answer to the question(s): can this salt be formed only in cases when chlorides are present during the hydration process, or, the salt can be formed even after hydration products have been formed and chorides enter the concrete later on, and, how firm is the 'bonding' of chlorides in the salt, i.e. how likely is it that the chlorides may become mobile and be available to depassivate the reinforcing bars. For more information and discussion on the subject, one may use the following link. 1. http://www.sciencedirect.com/science/article/pii/S0008884698001628
23	How can the values of the surface chloride concentration and the coefficient of diffusion be determined from given chloride concentration profiles	Interesting and relevant leads or clues can be seen in the following reference. 1. http://www.claisse.info/My%20papers/Paper%2037.pdf
24	From available literature, study the difference in chloride concentration profiles for different environmental conditions, different cement types and different water-cement ratios.	Following references could serve as a starting point for the search by a motivated student. 1. http://www.civil.northwestern.edu/people/bazant/PDFs/Backup%20of%20Papers/378.pdf 2. http://www.concrete.net.au/publications/pdf/ChlorideResistance.pdf
25	Study the manufacturing process of epoxy-coated reinforcing bars	Though there is no substitute to actually visiting a manufacturing unit to get first hand information on the subject as only then does one become sensitized to issues of quality and quality control as far as epoxy-coated bars are concerned. Information about the manufacturing process is also available on the internet and the following links could be useful starting points. 1. http://epoxyinterestgroup.org/index.cfm/epoxy/manufacturing 2. http://en.wikipedia.org/wiki/Fusion_bonded_epoxy_coating

26	Find out details of the various tests discussed – bending, impact resistance, holidays, durability, etc	More than the tests themselves, it is important that the spirit and the thought process behind prescribing a test (and for that matter a test method) is understood. The fact that epoxy-coated bars are products for use in reinforced concrete should not be lost sight of when designing the parameters for testing and the test methods. The following are only illustrations of this basic thought process and should be viewed in that light. Bending test 1. ASTM DESIGNATION: A 934/A 934M,Section-9.3 2. http://www.dot.ca.gov/hq/esc/ctms/pdf/CT_686feb08.pdf 3. IS 13620 : 1993, Section-A-4 4. JSCE-E 515 Impact resistance 1. ASTM G14 - 04(2010)e1, Standard Test Method for Impact Resistance of Pipeline Coatings (Falling Weight Test) 2. http://enterprise.astm.org/SUBSCRIPTION/filtrexx40.cgi?+REDLINE_PAGES/G14.htm 3. IS 13620 : 1993, Section-A-7 4. JSCE-E 514 Holiday testing 1. ASTM G62 – 07, Standard Test Methods for Holiday Detection in Pipeline Coatings 2. http://enterprise.astm.org/SUBSCRIPTION/filtrexx40.cgi?+REDLINE_PAGES/G62.htm 3. JSCE-E 512 4. http://www.dot.ca.gov/hq/esc/ctms/pdf/CT_685feb08.pdf Chemical resistance 1. IS 13620 : 1993, Section-A-2 2. JSCE-E 528 3. ASTM G20 – 10, Standard Test Method for Chemical Resistance of Pipeline Coatings 4. http://enterprise.astm.org/SUBSCRIPTION/filtrexx40.cgi?+REDLINE_PAGES/G20.htm
27	Find out about principle and methods of measurement of thickness in an epoxy coated reinforcing bar.	Relevant information may be found at the following links and references. 1. JSCE-E 515 2. http://www.dot.ca.gov/hq/esc/ctms/pdf/CT_687feb08.pdf 3. ASTM G12-83, Standard Test Method for Nondestructive Measurement of Film Thickness of Pipeline Coatings on Steel 4. ASTM G12 - 07(2013): http://enterprise.astm.org/filtrexx40.cgi?+REDLINE_PAGES/G12.htm
28	How does the cost of epoxy-coated bars compare with normal reinforcing bars	Relevant information may be found at the following links and references. 1. http://www.concreteconstruction.net/images/Choices%20in%20Corrosion-Resistant%20Rebar_tcm45-347334.pdf

		2. http://www.virginiadot.org/vtrc/main/online_reports/pdf/09-r9.pdf
29	Study the applications of CFRM in other industries such as automobile, aviation and sport.	Relevant information may be found at the following links and references. 1. http://composite.about.com/od/aboutcarbon/a/Carbon-Fiber-In-Sports.htm 2. http://composite.about.com/od/aboutcarbon/a/Applications-Of-Carbon-Fiber.htm 3. http://link.springer.com/content/pdf/10.1007%2Fs11837-006-0234-2.pdf 4. http://www.wiley-vch.de/books/biopoly/pdf_v10/vol10_16.pdf
30	Study the manufacturing process of the CFRM	Relevant information may be found at the following links and references: 1. http://www.aerosol.co.il/files/article/1315851198c98Ug.pdf Filament winding 1. http://www.cadfil.com/filamentwindingprocess.html Prepeg layup 1. http://www.hexcel.com/Resources/DataSheets/Brochure-Data-Sheets/Prepreg_Technology.pdf

Pultrusion:

1. http://www.strongwell.com/about/the-pultrusion-process/
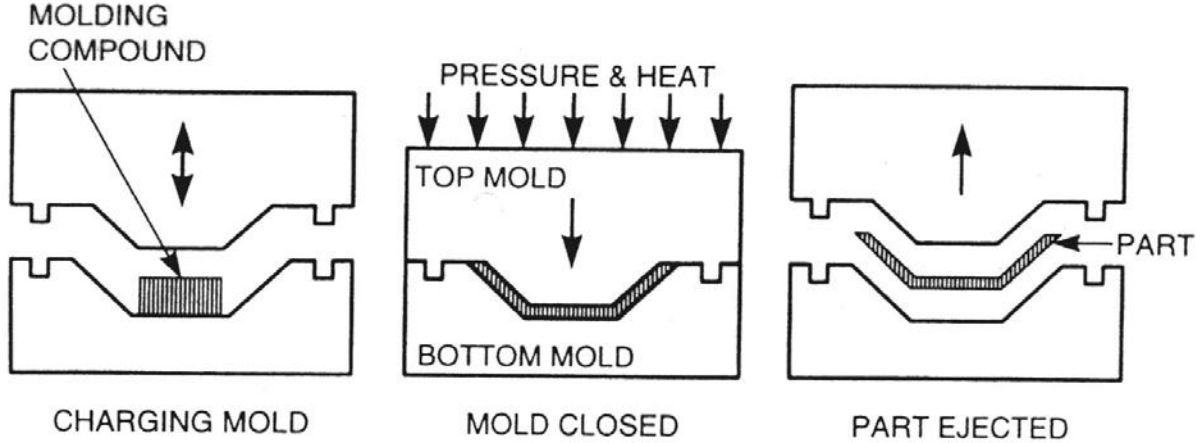
Resin transfer molding(RTM)
1. http://www.rtmcomposites.com/tooling/resin-transfer-moldingrtm

		Compression molding 1. http://www.efunda.com/processes/plastic_molding/molding_compression.cfm MOLDING COMPOUND PRESSURE & HEAT TOP MOLD BOTTOM MOLD PART CHARGING MOLD MOLD CLOSED PART EJECTED Vacuum bagging 1. http://www.bertram31.com/proj/tips/vaccuum.htm
31	What is the cost of different CFRM variant available in the market.	Relevant information may be found at the following links and references. 1. http://jushifrp.com/profile.htm 2. http://www.frpservices.com/North_america/EN/B/composite-introduction.html

32	Derive relation equations for load sharing, modulus of elasticity, critical fibre volume, shear modulus, etc. for CFRM as a function of the properties of the matrix and the fibres	Minimum fiber volume fraction $\sigma_c = \sigma_f V_f + \sigma_m (1-V_f)$ (1) If we assume all the fibres fail at the same time (the failure strain of the fibres is less than the matrix), under these conditions the ultimate longitudinal strength (σ_{cu}) of composite can be assumed equal to the composite stress at the fibre fracture strain, ϵ_{f*} equation (1) can therefore be used to obtain $\sigma_{cu} = \sigma_{fu} V_f + (\sigma_m) \epsilon_{f*}(1-V_f)$ (2) Where σ_{fu} is ultimate strength of fibres, and $(\sigma_m) \epsilon_f^*$ is the matrix stress at the fibre fracture strain ϵ_f^*. If the fibre volume fraction is small, i.e. below Vmin, the matrix will be able to support the entire composite when all the fibres break. At the composite strains higher than the fibre fracture strain, the composite will eventually fail when the matrix stress equals its ultimate strength (σ_{mu}). Thus, for fibre volume fraction less than V_{min} equation (1) can be written as $\sigma_{cu} = \sigma_{mu}(1-V_f)$ (3) Now V_{min} can be defined as the minimum fibre volume fraction that ensures that ensures fibre controlled composite failure. V_{min} can be obtained by equating right hand sides of equation (2) and (3). Thus $$V_{min} = \frac{\sigma_{mu} - (\sigma_m)_{\varepsilon_f^*}}{\sigma_{fu} + \sigma_{mu} - (\sigma_m)_{\varepsilon_f^*}}$$ For strengthening action σ_{cu} in $eq^n(2) \geq \sigma_{mu}$ $\sigma_{cu} = \sigma_{fu} V_f + (\sigma_m) \epsilon_{f*}(1-V_f)) \geq \sigma_{mu}$ $$V_{crit} = \frac{\sigma_{mu} - (\sigma_m)_{\varepsilon_f^*}}{\sigma_{fu} - (\sigma_m)_{\varepsilon_f^*}}$$
33	Why are fibrous materials 'stronger' than 'bulk materials'	Imperfections/flaws are prone to exist in bulk material, and the presence of a flaw in the form of a crack perpendicular to loading direction would reduce the measured strength substantially (compared to any theoretical value). The flaws present in any other direction would also reduce the strength – though to a lower extent. Relevant information may be found at the following links and references. 1. http://www.intertek.com/polymers/composites/test-methods/ 2. http://enterprise.astm.org/SUBSCRIPTION/RELATED/D6115_related.html
34	Carefully study the design and fabrication of the ends that hold the specimen in a tensile, tensile fatigue and creep tests.	More than the tests themselves, it is important that the spirit and the thought process behind prescribing a test (and for that matter a test method) is understood. The fact that epoxy-coated bars are products for use in reinforced concrete should not be lost sight of when designing the parameters for testing and the test methods. The following are only

illustrations of this basic thought process and should be viewed in that light.

Tensile test
1. http://www.mtu.edu/materials/k12/experiments/tensile/
2. http://www.shimadzu.com/an/industry/petrochemicalchemical/i127.html
3. http://www.instron.in/wa/acc_catalog/prod_list.aspx?cid=849&cname=Fiber%20Test%20Grips

Creep test
1. http://enterprise.astm.org/filtrexx40.cgi?+REDLINE_PAGES/C1337.htm

Fatigue test and test machine
1. http://enterprise.astm.org/filtrexx40.cgi?+REDLINE_PAGES/D6115.htm
2. http://onlinelibrary.wiley.com/doi/10.1111/j.1747-1567.2011.00713.x/pdf

35	Study some of the fibres used in fibre reinforced concrete.	Relevant information may be found at the following links and references. 1. http://www.stewols.com/Products/steel-fibre.html 2. http://www.steelfiber.org/ 3. ASTM A820 / A820M - 11 Details of steel fibermay be found at the following links and references 1. ASTM D578 / D578M - 05(2011)e1- Details of glass fibre 2. ASTM D4018 - 11 3. Standard Test Methods for Properties of Continuous Filament Carbon and Graphite Fiber Tows
36	Study some real applications of fibre reinforced concrete from the point of view of mix proportions, properties, etc	Relevant information may be found at the following links and references. 1. http://www.scribd.com/doc/60957876/Fibre-Reinforced-Concrete 2. http://www.betong.net/ikbViewer/Content/779358/S89%20-%20Anette%20Jansson%20et%20al%202008-07-07_just%20af%20DB_FINAL.PDF
37	Codes often give empirical formulae for estimating properties such as the tensile and flexural strength. Are these the same for fibre reinforced concrete	Reference may be made to the website given below for some relevant information. A motivated student may also carry out an additional exercise of comparing the empirical equations for normal concrete and fibre reinforced concrete. It may also be of interest to check provisions for the different types of fibres – steel, polypropylene, etc. 1. http://www.docstoc.com/docs/38966347/Design-methods-of-fibre-reinforced-concrete
38	What are the available codes and specifications that can be used as references for design of fibre reinforced concrete structures	Relevant information may be found at the following links and references. 1. ASTM C1116-00 2. ACI 440.6-08
39	Learn more about the models of hydration of cement	Hydration of cement has attracted a lot of attention of analysts and some of the websites given below provide relevant information. It may be borne in mind that a good model for studying hydration could go a very long way in promoting rapid

development in the field of cement chemistry and concrete engineering.

1. http://web.iitd.ac.in/~bishnoi/files/ShashankBishnoiPhDThesis.pdf
2. http://www.degas.nuac.nagoya-u.ac.jp/ippei/paper_e/2003_EASEC9_390.pdf
3. http://www.google.co.in/url?sa=t&rct=j&q=&esrc=s&source=web&cd=9&ved=0CGAQFjAI&url=http%3A%2F%2Fw
   ww.researchgate.net%2Fpublication%2F225666603_Critical_observations_for_the_evaluation_of_cement_hydrati
   on_models%2Ffile%2F9fcfd50f9a23e7cc22.pdf&ei=C--hUaOKE4PMrQe094CIBQ&usg=AFQjCNGiNSJvhi-
   DtJdGAk___oELQVkpSw&bvm=bv.47008514,d.bmk&cad=rja

40	Study applications of fracture mechanics principles to concrete engineering, especially high strength concrete	Fracture mechanics is essentially the science of formation and propagation of cracks. The heterogeneous nature of concrete makes the application of the principles to concrete very challenging. Effort in published literature focuses on applications in the area of high strength concrete, where parameters other than purely (or simply) compressive strength may not be sufficient to characterize the concrete, or cement paste, etc. Effort has also been made to apply the principles to fibre-reinforced concrete, where too the designer may be interested to use the additional toughness, and post-cracking load carrying capacity in the concrete to an advantage. The reader may also find the following documents useful in this regard. 1. http://www.civil.northwestern.edu/people/bazant/PDFs/Papers/S25.pdf 2. http://www.civil.northwestern.edu/people/bazant/PDFs/Papers/264.pdf
41	List and study proportions of high strength concrete used in different projects around the world. Observe parameters such as the maximum size of the coarse aggregate used, details of the paste composition, testing and quality control	As discussed in the class too, high strength concrete is essentially obtained through a combination of low water-cement ratio, high cement content, use of appropriate chemical admixtures (super plasticizers,etc.) , use of mineral admixtures (silica fume, flyash, etc.). Also, as the strength of concrete increases, special attention also needs to be paid to issues such as the choice and specifications for coarse aggregates, quality control (curing conditions, testing conditions for QC specimens) and so on. Lastly, from a purely engineering point of view, it is equally important that the material is used in real life projects that throws in issues such as transportation, quality control, curing, and so on. The question is directed to present to a motivated student an opportunity to study the composition and other aspects of developing and using high strength concrete in real structures. The reader may also find the following link useful in this regard. 1. http://www.sciencedirect.com/science/article/pii/0950061896000128
42	List and study 'special' provisions for design of concrete structures using high strength concrete	The reader may also find the following documents useful in this regard. 1. http://www.nap.edu/openbook.php?record_id=14496&page=1 2. http://www.bca.gov.sg/Publications/others/Design_Guide_on_use_of_High_Strength_Concrete.pdf
43	Obtain specific information about the heat of hydration of different cements	The heat of hydration of a cement may be taken to be the sum of the heats released by the different components of the cement (tri-calcium aluminate, tri- and di- calcium silicate, etc.) and their relative composition. It should also be remembered that the heat of hydration continues to be released for a long period of time, just as the hydration process.

		The reader may also find the following documents useful in this regard. 1. Concrete: Microstructure, Properties and Materials (PK Mehta and PJM Monteiro); Chapter 6 2. Properties of concrete (AM Neville); Chapter 1
44	Study the mix proportions used for the major concrete dams in the world.	Issues such as the heat of hydration and thermal cracking, which are important from the point of view of design of concrete mixes on the one hand to placing and curing issues (timing, duration) have already been dealt with in the lecture. The question is targeted to readers who may like to relate to and understand these aspects in more real terms such as the proportions and construction methods adopted in different dam projects in the world. The following links contain useful information in this regard. 1. http://www.hpcbridgeviews.com/i63/Article3.asp 2. http://rizzoassoc.com/cms/images/stories/site/published_papers/saluda_dam_remediation_rcc_mix_design_program.pdf
45	- Study a case study on pre-cooling and pipe cooling application in concrete construction	Issues such as the heat of hydration and thermal cracking, which are important from the point of view of design of concrete mixes on the one hand to placing and curing issues (timing, duration) have already been dealt with in the lecture. Precooling of concrete – primarily targeted to reduce the temperature of fresh concrete and achieved through means such as use of ice flakes, lowering the temperature of ingredients, etc. and post-cooling – achieved through taking away or removing the heat of hydration through circulation of cold water in pre-embedded pipes, are two of the basic methods for addressing the problems of mass concrete. The question is targeted to readers who may like to relate to and understand these aspects in more real terms such as the methods adopted in different dam projects in the world. The following links contain useful information in this regard. 1. http://www.ce.berkeley.edu/~paulmont/165/Mass_concrete2.pdf 2. http://www.bpesol.com/bachphuong/media/images/book/2074r_93.pdf
46	Study different specifications relating to construction using mass concrete	Issues such as the heat of hydration and thermal cracking are critical for mass concretes, and several parameters such as the peak temperature reached, temperature rise during hydration, (maximum) ratio of the tensile strength and the tensile stress (at the same point of time), etc. can be some of the parameters that a designer can lay down as 'conditions' for design of concrete mixes and plan for the placement of the concrete. 'Prescriptive' methods such as a limit on the cement content, placing temperature, etc. also serve the same purpose. Precooling of concrete – primarily targeted to reduce the temperature of fresh concrete and achieved through means such as use of ice flakes, lowering the temperature of ingredients, etc. and post-cooling – achieved through taking away or removing the heat of hydration through circulation of cold water in pre-embedded pipes, are two of the basic methods for addressing the problems of mass concrete, and achieve the required targets. The question is targeted to readers who may like to relate to and understand these aspects in more real terms such as the methods adopted in different dam projects in the world. The following links contain useful information in this regard. 1. ACI committee 207

| | | 2. IS 515:1959 |
		3. *IS 383*
47	Study the properties of concrete in the initial stages (say to an age of 3-7 days) more closely	It is amply clear that concrete is an extremely complex material that transforms from being more or less a liquid to being a solid over a period of time. To a large extent, this transformation can be controlled and 'designed' and mettle of the engineer is tested by the extent to which this transformation can be foreseen (and predicted), and corrective action taken if required, depending upon the early indications. This question acquires significance from the above perspective, and a reference to the following documents may useful in this regard. 1. Concrete: Microstructure, Properties and Materials (PK Mehta and PJM Monteiro); Chapter 6 2. Properties of concrete (AM Neville); Chapter 1
48	Study the effect of coarse aggregate properties on the properties such as the thermal expansion or conductivity of concrete	In several applications of concrete, its thermal properties such as the coefficient of linear expansion and the coefficient of conductivity are important for the designer. These properties are significantly affected by the properties and nature of the coarse aggregate used (besides the proportion, age, level of saturation, etc.). Some relevant values and information is available at the following. 1. http://www.arpnjournals.com/jeas/research_papers/rp_2012/jeas_0712_738.pdf 2. Concrete: Microstructure, Properties and Materials (PK Mehta and PJM Monteiro); Chapter 6 3. Properties of concrete (AM Neville); Chapter 8
49	Study available (suggested) methods for estimation of temperature of fresh concrete as a function of the temperature and proportion of constituent materials	It is intuitively clear that the temperature of the fresh concrete should be related to the temperature and properties of the ingredients (fine and coarse aggregate, cement and water) and their relative proportions. More information about this relationship, per se, can be seen in the following. 1. http://www.theconcreteproducer.com/aggregates/predicting-fresh-concrete-temperatures.aspx 2. http://construction.asu.edu/cim/Articles/Infrared.pdf 3. http://ftp.dot.state.tx.us/pub/txdot-info/cst/TMS/400-A_series/archives/422-0899.pdf
50	How do the properties of cement affect the effectiveness of chemical admixtures	It may be mentioned that compatibility of cement and the chemical admixture, which is essentially the issue of how properties of cement affect the effectiveness of chemical admixtures, is one of the areas that is attracting a lot of attention at present. Reference may be made to the following to better understand the effect of cement properties on the effectiveness of chemical admixtures (i.e. their ability to discharge their desired function - whether reducing the water content, or entraining air, or increasing or decreasing the setting time of concrete). Websites of chemical admixture manufacturers also at times provides pertinent information on the conditions of use, precautions to be observed, etc. depending upon the cement (and its properties). 1. http://www.ficci.com/events/20862/ISP/Elson%20John.pdf

		2. Concrete: Microstructure, Properties and Materials (PK Mehta and PJM Monteiro); Chapter 6 3. Properties of concrete (AM Neville); Chapter 5
51	Make a list of 'other' chemical admixtures.	Reference may be made to the following links for relevant information. 1. http://www.ce.memphis.edu/1101/notes/concrete/PCA_manual/Chap06.pdf
52	Prepare a note on HOW the chemical admixtures act.	As mentioned, chemical admixtures are used in concrete to reduce the water content, or entrain air, or increase or decrease the setting time of concrete. Apart from these, there are cases when chemicals are added to the concrete in small dosages for purposed such corrosion inhibition or sealing of pods and pores. Though the exact mechanism of the action of the chemical admixtures in not clearly understood, reference may be made to the following links for more information on the issue. 1. http://www.ce.berkeley.edu/~paulmont/241/chemical_admixture.pdf 2. Concrete: Microstructure, Properties and Materials (PK Mehta and PJM Monteiro); Chapter 8
53	Make a list of commercially available chemical admixtures.	It is obviously difficult to make an exhaustive list of chemical admixtures available. Reference may be made to websites of well-known manufacturers of chemical admixtures for more guidance on the matter. Some of the links that may be useful in this regard, are given below. 1. http://www.fosroc.com/Products/Cement_and_Concrete_Technology/Admixtures.aspx 2. http://ind.sika.com/en/system/search.html?_charset_=UTF-8&q=admixtures&btn_Search.x=0&btn_Search.y=0 3. http://dir.indiamart.com/impcat/concrete-admixture.html
54	Identify some major concrete construction projects in the world where chemical and mineral admixtures have been used	Modern concrete construction almost invariably involves use of mineral and chemical admixtures. In the case of the former, it should be noted that use of 'modified' cements, where pozzolonic materials (flyash, blast furnace slag, etc. have been pre-added) can also be considered included in the list. Some of such projects include Field Museum in Chicago, Hoover Dam, the Panama Canal and the Sears Tower, Eddystone Lighthouse, Pont du gard, Honshyu-Shikoku chain of bridges, etc.
55	Study classification of cement in the light of the cement composition	It should be borne in mind that the properties of a cement are essentially related to the properties of the component solid complexes and their relative presence in the cement. The other side of this coin is the ability to engineer the composition of a cement to suit a particular requirement. This concept is used by national standards to classify cements into different 'types' in terms of applications, etc. Reference may be made to the following for more information on the subject. 1. Concrete: Microstructure, Properties and Materials (PK Mehta and PJM Monteiro); Chapter – 6, Section-6.8 2. Concrete Technology (ML Gambhir), Chapter 2 3. http://petrowiki.org/File%3ADevol2_1102final_Page_384_Image_0002.png 4. http://iti.northwestern.edu/cement/monograph/Monograph3_8.html
56	Learn more about the chemistry and kinetics of the hydration reaction(s).	Though as an end-user of cement, a civil engineer need not be fully conversant with the hydration reactions and the required chemistry and kinetics, and may leave them to a professional cement chemist, but it is always a good idea to have at least a working knowledge of the process that is absolutely critical in concrete engineering (and that is surely the

		professional domain of an engineer).
		Some suggested references that may provide relevant leads in better understanding of the hydration process are given below.
		1. Concrete: Microstructure, Properties and Materials (PK Mehta and PJM Monteiro); Chapter – 6, Section-6.3 2. http://www.asocem.org.pe/bivi/sa/dit/icem/rx153.pdf 3. http://web.iitd.ac.in/~bishnoi/files/ShashankBishnoiPhDThesis.pdf
57	Study the effects of addition of mineral and chemical admixtures on the hydration process.	Chemical admixtures like accelerating admixtures, WR, HRWR increase rate of hydration. On the contrary, retarders decreases rate of hydration. Mineral admixtures decrease rate of hydration as the reaction rate of SCMs and CH is slow.
58	What is the role of entrained air in enhancing the freezing and thawing resistance of concrete	Air entrainment has the following effects: (a) increase workability of the concrete while it is in a plastic state, (b) enhance durability of concrete under conditions of cyclic freezing and thawing, and, (c) adverse affect of the strength due to an increase in the void content in concrete. Concrete can be assumed to have some 'free' water within its pore system and when this water freezes, it expands by around 9%. This causes hydraulic pressure within the concrete pore structure, which is susceptible to disintegration under these conditions. As concrete reaches its saturation point, and over many cycles of freezing and thawing, this pressure causes tensile forces to build up in the concrete matrix. If these forces exceed the internal tensile strength of the concrete, it will cause the concrete to deteriorate by way of general disruption, cracking, scaling or pop outs leaving it exposed to further attack and ultimately failure. These cracks can be prevented (or the pressure build-up relieved) by allowing the expansion of frozen water in the hardened concrete by introducing air using air entraining agents. These agents create a large number of closely spaced, small air bubbles in the hardened concrete. The air bubbles relieve the pressure build-up caused by ice formation by acting as expansion chambers. The measure is effective when the air-bubbles are well distributed and have are appropriately spaced in the cement paste. Usually about 4% air by volume is needed to ensure adequate protection, and codes of practice provide guidelines in the matter. It should be borne in mind that the amount of air needed to ensure adequate protection also depends on factors such as the size of aggregate used, severity of the weather conditions, etc. More information on the subject is available at: 1. http://www.ecocem.ie/technical,freeze_thaw.htm 2. Concrete: Microstructure, Properties and Materials (PK Mehta and PJM Monteiro)
59	Briefly discuss the difference in the compressive strength of concrete cubes and concrete cylinders.	Cylindrical and cubical specimens are used for testing of concrete internationally. For example, in India 150 mm cubes are used for concrete (and a smaller version is used for mortar and cement testing). On the other hand, the ACI code of practice and Japanese standards required the concrete to be tested using standard 150 X 300 mm (or 100 X 200 mm) cylinders. If one draws a simple schematic representation of the testing of cubes and cylinders. It can be seen that (a) the contact area is higher in the case of standard cubes with the plates of the testing machine in comparison with the contact area of the standard cylinder, (b) Under compressive loads both cube and cylinder tends to expand in the direction perpendicular to loading. Since the contact area of cube is more than the cylinder, the resultant friction at the interface produces better confinement in case of cubes than in cylinders and tends to increase the compressive strength of cubes, and, (c) a large portion of cylinder remains unconfined and the severe cracking in this region cause the cylinder to fails earlier than the corresponding cube.

		It may also be relevant to point out that cores drawn from structures are often used to determine the 'actual' strength, and they too are circular in cross-section and vary in the diameter to height ratio, and codes of practice provide guidelines for interpreting the results, whether the quality control per se is done using cubes or cylinders.
60	Why mercury but no other liquid is used in MIP?	Though hazardous for handling, its non-wetting property and high surface tension makes mercury an ideal liquid for porosimetry. Since mercury does not wet most substances and will not spontaneously penetrate pores by capillary action, it needs to be forced into the pores through external pressure. The required equilibrated pressure is inversely proportional to the size of the pores, only slight pressure being required to intrude mercury into large macropores, whereas much greater pressures are required to force mercury into small pores. The following document may be referred to for additional information and details. http://www.micromeritics.com/Repository/Files/Mercury_Porosemitry_Theory_poster_.pdf
61	What is the role of course aggregates in concrete mix?	Aggregates are essentially inert fillers and constitute a very integral part of concrete and accounts for 60 to 80 percent the volume and 70 to 85 percent the weight of the concrete. Aggregates are essential in concrete from the point of view of economy (since cement is expensive), dimensional stability (aggregates do not easily creep or shrink), stiffness, and abrasion resistance. The fact that they are generally available locally, makes them an ideal choice for use as 'fillers'. Though they are generally inert (i.e. they do not react with the pore water (or solution)), presence of certain minerals which react chemically with the components of the pore solution, makes the aggregates 'reactive' (as in the case of alkali aggregate reaction).
62	Describe direct, splitting and flexural tensile strength of concrete and discuss difficulties in measuring direct tensile strength of concrete	Though tests using dog bone (or dumb-bell) shaped specimens have been sometimes used for research purposes, especially in fracture mechanics related research, or, in studying fibre reinforced cementitious materials, the use has largely restricted to paste and mortar levels and very rearely concrete has been tested in that manner. However, in view of the need to estimate the tensile strength of concrete (to determine resistance to cracking), several alternative (surrogate) tests have been developed and are extensively used. Some of the standards that describe these tests are • ASTM Test Method for Flexural Strength of Concrete (Using simple Bean with third point loading) (C 78) • ASTM Test Method for Flexural Strength of Concrete (Using simple Bean with center point loading) (C 293) • ASTM Test Method for Splitting Tensile Strength of Cylindrical Concrete Specimens (C 496) • Methods of tests for strength of concrete (IS 516: 1959) • Splitting Tensile Strength of Concrete Method of Test (IS 5816 : 1999) **Method for flexural strength of concrete:** In the third point method a concrete beam of 150X150X535 mm in size, is supported at the ends and loaded at third points until failure. The modulus of rupture is calculated as the stress at the extreme fiber. In the center point test the beam is loaded at its mid span. In the former case, the middle third of the beam spam is subjected to maximum bending moment, the thus the maximum extreme fiber stress. In the center point loading, however, only the cross section at the mid-point is subjected to maximum moment and maximum extreme fiber stress. The possibility of having weak concrete in a region of higher stress is lower with the center point loading compared with the third point loading. As a result, for a given beam size, flexural strengths obtained from third point loading are lower than those obtained by center point loading; differences of 15% are not unusual. Variability is also low for third point loading. **Method of Splitting Tensile Strength of concrete:** In this test, a concrete cylinder core is compressed parallel to its axis, resulting in a splitting failure. The tensile strength is

		calculated from the peak compressive load. The results from this test are believed to be close to the actual tensile strength of concrete than those measured in flexural strength testing. Also, the tensile splitting test is less variable and easier to conduct. *Source: Guidelines for concrete mixtures containing supplementary cementitious materials to enhance durability of bridge decks; NCHRP REPORT 566*
63	Describe briefly the attributes of elastic modulus with emphasis on initial tangent modulus, secant modulus and tangent modulus	The stress-strain curve of concrete is essentially non-linear, though the following observations can be made: a) Up to one third of the maximum compressive strength the stress strain curve is 'almost' linear; b) from that stress up to maximum stress it is curved ascending, c) beyond that it is curved descending. Obviously, in such a case, the term 'Young's modulus'needs to defined more precisely, and words such as elastic, secant or tangent modulus are used in this context. A brief discussion of the load carrying mechanism in concrete and its relation to the stress strain curve and different stages of cracking is given the reference cited below, which also explains the different moduli as mentioned above. More information can be found in: **Concrete: Microstructure, Properties and Materials (PK Mehta and PJM Monteiro)**
64	Describe the primary and secondary hydration reactions in context of mineral admixtures.	Alite (C_3S), Belite (C_2S), Aluminate (C_3A), and Ferrite (C_4AF) are the four main constituents of cement. The hydration reactions of these constituents can be referred to primary hydration reactions and are summarized below: Hydration of Calcium Silicates: $$2C_3S + 11H \rightarrow C_3S_2H_8 + 3CH$$ $$2C_2S + 9H \rightarrow C_3S_2H_8 + CH$$ Both CSH and CH are hydration products and CSH is primary strength-giving phase in Portland cement concrete. C_3S hydration is more rapid contributing to early age strength and C_2S hydrates slowly contributing to strength after 7-14 days. Hydration of the Calcium Aluminates and Ferrites Reaction of C_3A with water occurs very quickly and liberates a very large amount of heat, which if not controlled can lead to severe cracking in concrete. Gypsum ($C\$H_2$) is added to cement to control the hydration of C_3A. On mixing the water, both aluminates and ferrites first react with gypsum to form Ettringite($C_6A\$_3H_{32}$). Once gypsum is consumed, they react with Ettringite in presence of water and form monosulfate ($C_4A\$H_{12}$). $$C_3A + 3C\$H_2 + 26H \rightarrow C_6A\$_3H_{32}$$ $$C_4AF + 3C\$H_2 + 30H \rightarrow C_6A\$_3H_{32} + CH + FH_3$$ $$2C_3A + C_6A\$_3H_{32} + 4H \rightarrow 3C_4A\$H_{12}$$ $$2C_4AF + C_6A\$_3H_{32} + 12H \rightarrow 3C_4A\$H_{12} + 2CH + 2FH_3$$ Addition of Mineral Admixtures (MA) causes pozzolanic reactions or Secondary Reactions between Silica present in MA

and calcium hydroxide which is produced in primary reactions, and produces additional hydration products of very fine pore structure. The pozzolonic reaction can be represented as follows:

$$Ca(\text{OH})_2 + SiO_2 + 2H_2O \rightarrow CaH_2SiO_4.2H_2O$$

$$CH + S \rightarrow CSH$$
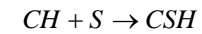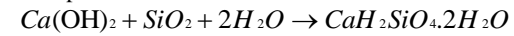
Calcium hydroxide (lime) depletes with time and its reaction affects the long-term gain of strength in concrete with Mineral Admixtures as compared to ordinary Portland cement concrete; however despite of this reduction, there is sufficient lime to maintain a high pH.

Reference may also be made to the following for more details:

1. Concrete: Microstructure, Properties and Materials (PK Mehta and PJM Monteiro)
2. Effects of different mineral admixtures on the properties of fresh concretes (S.U,Khan, M. F. Nuruddin, T. Ayub,N. Shafiq)