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2024 Materials Exam Learning Objectives

Introduction to Material Science

This Section details the properties of materials, how materials are made, their application and mechanisms that can lead to their deterioration and failure.

1. Describe the predominant and secondary bonding type in metals, ceramics, and polymers and how these bond types influence the mechanical and thermal behavior of materials.
2. Discuss how temperature, UV, and moisture affect various bonds and can lead to material failures.
3. Sketch and identify each of the following on a typical stress-strain curve for a material (metal, plastics, wood etc.): Hooke's Law, Plastic deformation, Tensile strength, Ductility, Toughness.
4. Discuss basic structure-property relationships in polymers (low and high density polyethylene, polypropylene, polyvinyl chloride) and in building enclosure materials (spun-bonded polyolefin, high-density polyethylene film, Building paper, Asphalt-saturated felt, EPDM Rubber, TPO, modified bitumen).

Masonry:

Manufacture and Properties

5. Describe the different materials of which a masonry wall system comprises and the function of each.
6. Define the standard masonry terminology, including different masonry material types, units, dimensions, shapes, unit area and voids (nominal versus actual dimensions, net area, cores or cells, frogs, face shells, webs, semi-hollow unit, hollow unit, and solid unit).
7. Define the four facets of concrete block classification (solid content, minimum compressive strength, concrete type and shrinkage).
8. Explain how masonry material properties, such as compressive strength, tensile strength, cold water absorption, boiling water absorption, c/b ratio, and freeze-thaw mass loss are used to describe the Grade and Type of clay brick and how they influence performance of masonry.
9. Compare and contrast different types of mortar (Portland Cement-Lime, Masonry Cement and Mortar Cement) and types of cement (M, S, N, O, and K).
10. Describe the most common mortar joint thickness and the profiles in masonry construction that are considered best practice.
11. Describe the manufacturing process of clay brick and concrete block.
12. Explain the difference between block strength and masonry strength.

Application

13. Describe the role of movement joints in masonry, and how to calculate the amount of expected movement utilizing the coefficients of thermal expansion and contraction.
14. Discuss the different ways masonry can be anchored or connected to its backup such as ties, helical ties, headers, row lock (solid masonry), shelf angles.

15. Describe Thin Stone (Brick) Masonry and how this is different from traditional masonry in terms of support, anchorage, application of rain screen, etc.

Deterioration & Repair

16. Identify moisture-related issues that can arise in masonry construction, such as subflorescence, efflorescence and spalling, and decay, their causes and how to avoid these issues in new and existing buildings.
17. Explain how freeze-thaw impacts masonry.
18. Identify the basics of how to repair and replace damaged masonry within a wall system (traditional masonry and historical buildings).

Metals:

Manufacture and Properties

19. Describe how the molecular structure of metals influences their conductivity, porosity, strength.
20. Describe how material selection impacts corrosion resistance (e.g. raw steel, galvanized steel, stainless steel, copper, aluminum).
21. Describe how to protect metal from corrosion including galvanized steel, powder coated metal.

Application

22. Discuss the importance of matching fastener and cladding metal types (i.e. consequences of dissimilar metals).
23. Discuss the various ways thermal bridging can be minimized with different metal choices and cladding attachment profiles and when metal substitutes are appropriate (e.g. fibreglass, high density plastics).

Deterioration & Repair

24. Explain the circumstances leading to, and the mechanisms of, metal corrosion.
25. Describe how basic electrochemical corrosion occurs in metals, specifically Steel, Aluminum and Copper.
26. Describe how hydrogen embrittlement in fasteners occurs and which metals are most susceptible.
27. Discuss how galvanic corrosion occurs between dissimilar metals.
28. Explain how cathodic protection can protect a metal from corrosion.

Concrete:

Manufacture and Properties

29. Explain how Portland cement is manufactured.
30. Define the roles of the phases in Portland cement (alite, belite, aluminate and ferrite).
31. Identify the purpose of main components in concrete and various cementitious repair materials. (water, cement, aggregates, various chemical admixtures, and different supplementary cementing materials).
32. Describe the process of hydration and how concrete gains strength.
33. Identify the various fresh concrete tests conducted and the fresh concrete properties they measure (i.e. slump/flow test, density, yield, and air content, strength testing).
34. Define water-to-cementitious materials ratio and how it affects concrete properties.
35. Discuss properties of hardened concrete that influence durability, such as strength, permeability, porosity, pore structure, and air entrainment.

36. Discuss properties of fresh concrete, including workability, concrete placement, finishing, setting and issues that can arise from improper placement and curing techniques.

Application

37. Discuss the application of concrete in terms of different exposure requirements (C, F, N, S and A exposure classes).
38. Describe various types of cement, such as Portland Cement (GU, HE, HS), Portland Limestone Cements, Blended Cements, and their uses.

Deterioration and Repair

39. Explain why plastic shrinkage cracks form and the influencing factors.
40. Explain the deterioration mechanisms (including cracking due to thermal stress, shrinkage and creep, freeze-thaw, chloride attack on rebar, carbonation corrosion, alkali-aggregate reactivity, sulfate attack and fire) and measures that can be taken to prevent/mitigate the various durability issues for concrete.
41. Describe the volume changes that concrete can undergo (i.e. swelling and shrinkage).
42. Explain de-passivation of steel reinforcing, what causes it, and what measures can be taken to prevent it.
43. Describe the process of investigation and condition assessment of concrete structures, including non-destructive and destructive evaluation methods, analysis of hardened concrete and diagnosis of deterioration.
44. Discuss techniques and methods for repairing concrete structures, including concrete removal, surface preparation, reinforcement preparation and repair.
45. List the types and properties of repair concretes and mortars (such as conventional concrete, dry pack mortars, fibre-reinforced concrete, pre-placed aggregate concrete, shotcrete, etc.), materials for surface treatments, and polymeric materials.
46. Select appropriate repair materials (common cementitious repair materials, including conventional concrete, polymer modified concrete, fibre-reinforcement, cementitious grouts, rapid-setting cement, preplaced aggregate concrete, shrinkage-compensating concrete and shotcrete) best suited for cases with varying environments, building materials, performance criteria, and repair application requirements.

Sealants:

Manufacture and Properties

47. Discuss curing, physical and chemical properties of various types of sealant materials (polyurethane, silicone, acrylic, butyl, and polymer modified bitumen).
48. Describe the function and use of different sealants.

Application

49. Describe various sealant joint types such as expansion, termination, butt (tensile), fillet, cap (needle) bead, lap, bridge (band-aid), and their applications.
50. Describe the relationship between joint design including joint profile, joint backing, substrate properties and expected joint movement.
51. Discuss sealant application process and the importance of surface preparation, proper tooling, and curing.
52. Describe laboratory and field testing of sealants with respect to compatibility, adhesion, and solvent migration.
53. Describe what a two-stage joint is, and why it is considered best practice.

Deterioration and Repair

54. Identify two mechanisms of sealant failure (cohesive and adhesive) and what leads to them.
55. Identify environmental factors that can lead to sealant degradation / deterioration.
56. Describe common repair strategies for replacing sealant joints.

Glass:

Manufacture and Properties

57. Describe the various types of manufactured glass including (laminated, tempered, float, wired, fire glass).
58. Describe the primary components and manufacturing process of the various types of manufactured glass.
59. Describe the principal properties (including tensile strength, flexural strength, optical properties, and thermal conductivity, that characterize glass of various types.

Application

60. Describe where the various types of manufactured glass are used in buildings and why.
61. Describe various window coatings and tints that could be used, and explain why.

Deterioration and Repair

62. Describe the defects incorporated into glass during manufacture and the effect on performance including various inclusions.
63. Describe the ways in which glass of various types fails and the causes of failure.

Wood:

Manufacture and Properties

64. Describe the differences in solid wood, engineered wood (LVL - laminated veneer lumber, PSL - parallel strand lumber, TJI, etc) and composite products (CLT - cross-laminted timber, NLT - nail-laminated timer, GL - glue-laminated).
65. Discuss the ideal moisture content within wood framing and what can happen to wood products when this ideal level is not maintained.
66. Understand various treatments used in wood such as Pressure Treatment (CCA - chromated copper arsenate, ACQ - alkaline copper quaternary), Fire Retarders, Mould Inhibitors, etc.
67. Define Mould, how it is caused within wood, and what its effects are on wood.
68. Explain how wood moves during shrinkage, drying, and swelling.
69. Compare shrinkage and expansion of different cuts of wood.

Application

70. Discuss the importance of matching fasteners with compatible wood treatment types.
71. Discuss how surface treatments of exposed wood components can enhance durability.

Deterioration and Repair

72. Describe factors that can affect wood products such as temperature, moisture, solar radiation and wind.
73. Identify situations that lead to decay in wood and how wood decay can best be controlled in both existing and new buildings.

74. Identify insects that can compromise the structural capabilities of wood, and what methods can be used to make wood resistant to insects.

Plastics:

Manufacture and Properties

75. Identify compatibility of different fastener types with different types of wood and/or wood treatments and what damages can result if improper fasteners are used.
76. Describe the difference between the two main types of plastic materials (thermoplastics, such as polyethylene, polystyrene, polypropylene, and polyvinyl chloride, and thermosets, such as polyesters, polyurethane, epoxy resins).
77. Discuss how water resistance and thermal conductivity vary in different plastics, and how these properties influence the use of plastics in buildings.
78. Explain mechanical properties of different plastics, including tensile strength, stiffness, toughness, hardness, creep and impact resistance and how they can be affected by temperature and environmental conditions.

Application

79. Identify different types of plastics that have high light transmission properties, and their uses in buildings.
80. Identify typical applications of plastic products, such uses of polyethylene, polystyrene, polypropylene, polyvinyl chloride, and polyurethane, in buildings.

Deterioration and Repair

81. Understand how different factors, including ultraviolet radiation, affect weathering and deterioration of plastics.

Membrane Type Materials:

Manufacture and Properties

82. Identify common products used as air barrier systems and vapour retarders (i.e. different sheet products, fluid applied air barriers, boards and spray foam).
83. Identify common products used for waterproofing.
84. Demonstrate an understanding of standard test methods used to evaluate performance of air barriers (materials and systems) and vapour retarders.
85. Explain the difference between air barriers and vapour retarders in terms of air and water vapour permeability.

Application

86. Discuss the application, benefits, and drawbacks of different air barrier and vapour retarder systems.
87. Describe how the following materials can be used to waterproof a wall/roof and limitations of each: bentonite clay, cementitious products, one and two-component liquid-applied membranes, spray foam.
88. Explain the difference between air barriers and vapour retarders in terms of application and installation requirements, such as continuity, durability and ability to withstand forces that may act on these systems.

Deterioration and Repair

89. Explain the factors that negatively affect durability and can cause deterioration of membrane type materials in buildings.
90. Understand the remedial actions that could be taken to address deterioration of membrane type materials in buildings.

Thermal Insulation:

Manufacture and Properties

91. Discuss the various properties (thermal, air, vapour, water transmission) of different types of insulation (loose fill, batts, blankets, rigid boards and foamed-in-place insulation) and how their manufacturing process affects these properties.

Application

92. Discuss the application, benefits, and drawbacks of different insulation materials.
93. Discuss the application, benefits, and drawbacks of using reflective thermal barrier materials.

Deterioration and Repair

94. Identify factors that reduce effectiveness of insulation in real world applications, including the reduction in long-term thermal resistance (LTTR).
95. Describe the factors that negatively affect durability and can cause deterioration of thermal insulation materials.