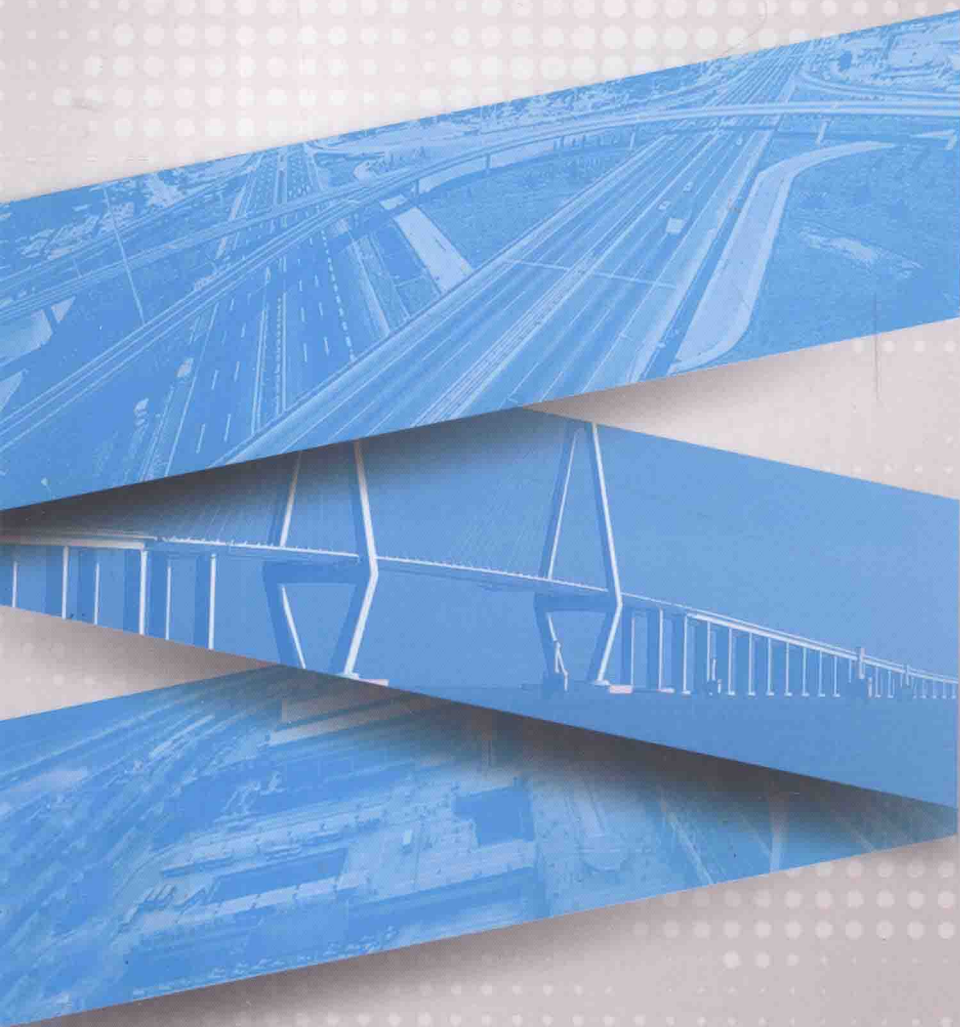


Construction Materials

土木工程材料

Zongjin Li, Yamei Zhang, Chris Leung, Yunsheng Zhang, Huisu Chen

李宗津 张亚梅 梁坚凝 张云升 陈惠苏



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PREFACE

Construction materials are the most widely used materials in the world. They are used to construct different infrastructure and private buildings, for both structural and non-structural applications. Understanding the composition, processing methods, mechanical properties and general performance of construction materials are essential for civil engineering students to meet the need in professional careers. Due to the rapid development in construction materials, the content of conventional text book in construction materials field needs to be updated. The motivation to write this book is try to fill in the vacancy by introducing new types of materials, new processing methodologies, new testing methods for property assessment, and innovative developments in technology. The unique features of this book include the introduction of basic mechanical behavior of the materials, emphasized fundamental exploration of materials composition and microstructure, and state of art of construction materials development and innovations. This book provides more comprehensive knowledge on construction materials technology including the systematic introduction of fibrous composite materials and functional cement-based materials.

The book is divided into ten chapters. Chapter 1 gives a brief introduction of construction materials, including its historic development, structural materials definition, materials physical and chemical properties, and new development trend of the construction materials. Chapter 2 provides the knowledge of mechanical behavior of construction materials, covering elastic, plastic, creep, fracture and fatigue. Chapter 3 discusses the properties of aggregates, focusing on grading and moisture content. Chapter 4 focuses on the binding materials such as non-hydraulic and hydraulic cement. Emphases are on the Portland cement. Chapter 5 covers the contents of concrete, the most important construction material. The chapter discusses the properties of concrete in both fresh and hardened stage. New testing method of noncontact resistivity measurement is introduced. Chapter 6 provides updated knowledge on steel, including corrosion protection and steel recycling. Chapter 7 introduces the basic knowledge of fibrous composites from their composition, mechanics to the application. It is new content for construction materials. Chapter 8 covers the essential knowledge of wood on its properties and applications. In chapter 9, the pavement materials have been introduced with the emphases on the asphalt concrete. Finally, chapter 10 discusses the non-structural materials, in which the functional materials are new in a book of construction materials.

The book is designed and written primarily to meet the teaching needs for

undergraduate students in civil engineering and materials engineering. However, it can serve as a reference or a guide for professional civil engineers in their practice.

In the process of writing this book, the authors received enthusiastic help and invaluable assistance from many people, which are deeply appreciated. The authors would like to express their special thanks to Dr. Yu Zhu, Miss Yu Cheng and for their help in editing the book draft. Mr. Mike Pomfret is acknowledged for his professional page proof reading.

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Zongjin Li , Yamei Zhang, Chris Leung, Yunsheng Zhang, Huisu Chen

Content

Chapter 1	Introduction	1
1.1	Historic development	1
1.2	Structural materials and structural design	2
1.3	Physical properties	3
1.3.1	Density, apparent density and packing density of matter	4
1.3.1.1	Density	4
1.3.1.2	Apparent density	4
1.3.1.3	Packing density	4
1.3.2	Porosity and void percentage	5
1.3.2.1	Porosity	5
1.3.2.2	Void percentage	6
1.3.3	Physical properties relevant to water	6
1.3.3.1	Hydrophilicity and hydrophobicity	6
1.3.3.2	Water adsorption	7
1.3.3.3	Hygroscopicity	7
1.3.3.4	Water resistance (coefficient of softening)	7
1.3.3.5	Water impermeability	7
1.3.3.6	Frost resistance	8
1.3.4	Physical properties relevant to thermal effects	8
1.3.4.1	Thermal conductivity	8
1.3.4.2	Thermal capacity and specific heat capacity	8
1.3.4.3	Thermal expansion	9
1.3.4.4	Fire resistance and refractoriness	9
1.4	Chemical properties	10
1.4.1	Reactivity	10
1.4.2	Activation energy	10
1.5	Principles in the selection of materials	11
1.6	Innovations and development trends in construction materials	12
1.6.1	Functional materials	12
1.6.1.1	Cement-based piezoelectric materials	12
1.6.1.2	Thin-walled low frequency sound shielding material	15
1.6.1.3	Controllable heat insulation building products with phase changing	

materials (PCM)	15
1. 6. 1. 4 Electromagnetic wave shielding and absorbing materials	17
1. 6. 2 Sustainability; Eco-friendly material development	20
1. 6. 2. 1 Recycle and reuse of industry waste	20
1. 6. 2. 2 New binders-energy efficient materials with less CO ₂	23
1. 6. 3 Multiple disciplinary integrated materials	24
1. 6. 3. 1 Nanotechnology in construction	24
1. 6. 3. 2 Dynamic shading window system (DSWS)	26
1. 6. 3. 3 Self-compacting concrete (SCC)	27
Discussion topics	28
References	28
Chapter 2 Mechanical behavior of materials	32
2. 1 Material behavior and structural performance	32
2. 2 Elastic behavior	34
2. 2. 1 Introduction	34
2. 2. 2 Physical basis of elastic behavior	34
2. 2. 3 Young's Modulus; definition, typical values and significance to structural design	35
2. 2. 4 Modulus of composite materials and application to reinforced concrete member	36
2. 3 Plastic behavior	38
2. 3. 1 Phenomenon of plastic yielding	38
2. 3. 2 Physical basis of plastic behavior	40
2. 3. 3 Modeling of plastic behavior	41
2. 3. 4 Illustration of plastic behavior with a parallel system	42
2. 4 Time dependent behavior—Creep	44
2. 4. 1 Phenomenon of time dependent behavior	44
2. 4. 2 Implications to structural design	44
2. 4. 3 Physical basis of time dependent behavior	45
2. 4. 4 Modeling of creep at low temperature with viscoelastic models	46
2. 4. 5 Strain response under arbitrary stress history—superposition	49
2. 5 Fracture	49
2. 5. 1 Introduction	49
2. 5. 2 Fast fracture; physical basis and modeling	50
2. 5. 3 Ductile to brittle failure transition of metal	53
2. 5. 4 Fatigue—phenomenon and empirical expressions	54
2. 5. 5 Physical basis of fatigue and K-based modeling	57
Discussion topics	58
Problems	59
References	62

Chapter 3	Aggregates	63
3.1	Introduction	63
3.2	Classification of aggregate	63
3.3	Aggregates produced from industrial waste	66
3.3.1	Blast furnace slag aggregate	67
3.3.2	Aggregates from recycled concrete	67
3.4	Properties of aggregates	68
3.4.1	Density of aggregate	68
3.4.2	Moisture conditions	69
3.5	Grading	70
3.5.1	Definition	70
3.5.2	Determination of the grading	71
3.5.3	Fineness modulus	72
3.5.4	Fineness modulus for blending of aggregates	73
3.6	Shape and surface texture	73
3.7	Deleterious substances	74
3.8	Soundness	75
	Discussion topics	76
	Problems	76
	References	77
Chapter 4	Binder materials	78
4.1	Organic binders	78
4.1.1	Asphalt	78
4.1.1.1	Introduction	78
4.1.1.2	Manufacture	78
4.1.1.3	Composition of asphalt	80
4.1.1.4	Properties of asphalt	81
4.1.1.5	Application	82
4.1.2	Polymers	83
4.1.2.1	Introduction	83
4.1.2.2	Composite and manufacture	83
4.1.2.3	Composite properties	84
4.1.2.4	Installation procedures for FRP application	84
4.1.2.5	Applications of FRP	85
4.2	Inorganic binders	85
4.2.1	Lime	85
4.2.1.1	Introduction	85

4. 2. 1. 2	Classification	86
4. 2. 1. 3	Manufacture	86
4. 2. 2	Gypsum	90
4. 2. 2. 1	Introduction	90
4. 2. 2. 2	Manufacture	91
4. 2. 2. 3	Classification	92
4. 2. 2. 4	Application	92
4. 2. 3	Water glass	93
4. 2. 3. 1	Introduction	93
4. 2. 3. 2	Properties	93
4. 2. 3. 3	Application	93
4. 2. 4	Portland cement	93
4. 2. 4. 1	Manufacture	94
4. 2. 4. 2	Chemical composition	99
4. 2. 4. 3	Hydration	100
4. 2. 4. 4	Type of Portland cement	113
4. 2. 4. 5	Properties of Portland cement	116
	Discussion topics	120
	References	121

Chapter 5 Concrete 123

5. 1	Introduction	123
5. 1. 1	Historic development	123
5. 1. 2	The applications of Portland cement concrete	124
5. 1. 3	Characteristics of concrete	126
5. 1. 3. 1	Advantages of concrete	126
5. 1. 3. 2	Limitations	128
5. 1. 4	Types of concrete	130
5. 1. 4. 1	Classification in accordance with unit weight	130
5. 1. 4. 2	Classification in accordance with compressive strength	130
5. 1. 4. 3	Classification in accordance with additives	131
5. 1. 5	Factors influencing concrete properties	131
5. 1. 5. 1	w/c ratio (or w/b or w/p ratio)	131
5. 1. 5. 2	Cement content	132
5. 1. 5. 3	Aggregate	132
5. 1. 5. 4	Admixtures	133
5. 1. 5. 5	Mixing procedures	133
5. 1. 5. 6	Curing	134
5. 2	Admixtures used for making concretes	134

5.2.1	Definition and classifications	135
5.2.2	Chemical admixtures	136
5.2.2.1	Water reducing admixtures	136
5.2.2.2	Setting control admixtures	137
5.2.3	Air-entraining admixtures	139
5.2.4	Mineral admixtures	142
5.3	Three-phase theory for concrete	146
5.3.1	Concept of the third phase—transition zone	146
5.3.2	Structure of the transition zone	148
5.3.3	Influence of the transition zone on properties of concrete	148
5.4	Fresh concrete	150
5.4.1	Definition	150
5.4.2	Workability	150
5.4.3	Measurement of workability	154
5.4.4	Setting of concrete	158
5.4.5	Placing, compacting and curing	159
5.4.5.1	Delivery of concrete	160
5.4.5.2	Placing of concrete	160
5.4.5.3	Compacting and finishing	161
5.4.5.4	Curing	161
5.5	Hardened concrete	163
5.5.1	Strength of hardened concrete	163
5.5.1.1	Control methods for strength test	164
5.5.1.2	Calibration of transducers	165
5.5.1.3	Compressive strength and corresponding tests	166
5.5.1.3.1	Failure mechanism	166
5.5.1.3.2	Specimen preparation for compression test	167
5.5.1.3.3	Factors affecting the measured compressive strength	167
5.5.1.4	Uniaxial tensile strength and corresponding tests	169
5.5.1.4.1	Failure mechanism	170
5.5.1.4.2	Stress concentration factor	170
5.5.1.4.3	Relationship between the compressive strength and tensile strength	170
5.5.1.4.4	Indirect tension test (split cylinder test or Brazilian test)	171
5.5.1.5	Flexural strength and corresponding tests	172
5.5.1.6	Behavior of concrete under multi-axial stresses	173
5.5.1.6.1	Behavior under biaxial stress	173
5.5.1.6.2	Behavior of concrete under triaxial stress	174
5.5.1.7	Fatigue strength of concrete	175

5.5.2	Stress-strain relationship and constitutive equations	177
5.5.2.1	Method to obtain a stress-strain (deformation) curves	177
5.5.2.2	Modulus of elasticity	179
5.5.3	Dimensional stability-shrinkage and creep	181
5.5.3.1	Shrinkage	181
5.5.3.1.1	Plastic shrinkage	181
5.5.3.1.2	Autogenous shrinkage	182
5.5.3.1.3	Drying shrinkage	183
5.5.3.2	Creep	186
5.5.3.2.1	Phenomenon of creep	186
5.5.3.2.2	Influence of creep on reinforced concrete	187
5.5.3.2.3	Mechanism of creep in concrete	188
5.5.3.2.4	Importance of applied stress level to creep	189
5.5.3.2.5	ACI equation for predicting creep	189
5.5.3.3	Test method for creep	190
5.5.3.4	Other important factors affecting shrinkage and creep	190
5.5.4	Durability	191
5.5.4.1	Causes of deterioration and main durability problems	192
5.5.4.2	Basic factors influencing the durability	193
5.5.4.3	Measurement of permeability coefficient	195
5.5.4.4	Measurement of diffusivity coefficient	197
5.5.4.5	Cracks in concrete	199
5.5.4.6	Corrosion of reinforcing steel	200
5.5.4.6.1	Carbonation-induced corrosion	200
5.5.4.6.2	Chloride-induced corrosion	202
5.5.4.6.3	Corrosion mechanisms	204
5.5.4.7	Alkali-aggregate reaction	210
5.5.4.8	Deterioration caused by Freeze-thaw	214
5.5.4.9	Degradation caused by sulfate attack	216
5.5.4.10	Durability in marine environment	220
5.5.4.11	Deterioration of concrete caused by multi-factors	222
	Discussion topics	223
	Problems	225
	References	226

Chapter 6 Steel 231

6.1	Classification	231
6.2	The manufacture and strengthening of steel	232
6.2.1	Cold and hot working	233

6.2.2	Heat treatment	234
6.2.3	Surface treatment	235
6.3	Structure and properties of steel	236
6.3.1	Structure of steel	236
6.3.2	Mechanical properties of steel	236
6.3.3	Relationship of steel properties to composition and manufacturing process	239
6.3.4	Effect of alloying elements	242
6.3.5	Failure of steel under multiaxial stress	243
6.4	Steel welding and associated problems	245
6.4.1	Embrittlement due to martensite formation	245
6.4.2	Lamellar tearing	246
6.5	Corrosion protection of steel	247
6.5.1	Mechanisms of steel corrosion	247
6.5.2	Corrosion protection with paint/coatings	248
6.5.3	Cathodic protection	248
6.5.4	Designs to minimize the potential of corrosion	249
6.6	Application and recycling of steel	250
6.6.1	Application	250
6.6.2	Recycling	250
	Discussion topics	251
	Problems	251
	References	253
Chapter 7	Fiber reinforced polymer composites	254
7.1	Introduction	254
7.2	Advantages of fiber reinforced composite and general applications	254
7.3	Raw materials and processing techniques	256
7.3.1	Polymer matrix	256
7.3.2	Fibers	257
7.3.3	Processing of fiber reinforced polymeric composites	259
7.4	Behavior of aligned continuous fiber composites	260
7.4.1	Elastic properties	261
7.4.2	Micromechanical equations for the elastic properties	263
7.4.3	Composite strength	264
7.5	Application of fiber reinforced composites in civil engineering	265
7.5.1	Glass fiber reinforced polymer bars for concrete structures	265
7.5.2	Strengthening of concrete structures with carbon fiber reinforced polymer	267
7.5.3	Fiber reinforced polymer components for buildings and bridges	269
	Discussion topics	271

Problems	272
References	272
Chapter 8 Wood	273
8.1 Introduction	273
8.2 Structure of wood	274
8.3 Properties of wood	276
8.3.1 Physical properties	276
8.3.2 Elastic properties	277
8.3.3 Strength and toughness of wood	278
8.3.4 Time dependency of wood properties	280
8.3.5 Behavior of wood in a fire	281
8.4 Grading of wood	281
8.5 Wood products	282
8.6 Wood degradation and protection	284
Discussion topics	284
References	285
Chapter 9 Pavement materials	286
9.1 Introduction	286
9.1.1 Pavement types	286
9.1.2 Bitumen materials	288
9.1.3 Quality control of underlying soil (subgrade)	289
9.2 Petroleum asphalt	290
9.2.1 Original asphalt	290
9.2.2 Modified asphalt using polymers	291
9.3 Asphalt concrete	293
9.4 Testing of asphalt properties	295
9.5 Design of asphalt mixture	295
Discussion topics	299
References	299
Chapter 10 Major non-structural materials	300
10.1 Partitions	300
10.1.1 Brick partitions	300
10.1.2 Glass partitions	301
10.1.3 Concrete partitions	301
10.1.4 Fibre cement sheet partitions	302
10.1.5 Timber partitions	303

10.2	Decoration materials	303
10.2.1	Coatings	303
10.2.2	Paint	304
10.2.3	Tiles	304
10.2.3.1	Roof tiles	305
10.2.3.2	Floor tiles	305
10.2.3.3	Ceiling tiles	306
10.2.4	Glass	306
10.2.4.1	Glass composition	306
10.2.4.2	Color of glass	307
10.3	Function materials	307
10.3.1	Waterproofing	307
10.3.2	Fireproofing	308
10.3.3	Soundproofing	309
10.3.4	Building insulation materials	310
10.3.4.1	Spray foam insulation	311
10.3.4.2	Insulating concrete forms	311
10.3.4.3	Rigid panels	312
10.3.4.4	Batts	313
10.3.4.5	Loose-fill insulation	313
10.3.4.6	Aerogels	314
10.3.4.7	Straw bales	315
10.3.5	Sealants	316
	Discussion topics	317
	References	317
	Construction Materials Laboratory	319
	Laboratory I : Aggregate	319
	Laboratory II : Cement	323
	Laboratory III : Fresh concrete	327
	Laboratory IV : Testing methods of mechanical properties of ordinary concrete (GB/T 50081—2002)	329
	Laboratory V : Two demo tests	331
	Laboratory VI : Hardened concrete tests (28 day properties)	334
	Laboratory VII : Non-contact resistivity measurement; a demonstration	338
	Index	340

Chapter 1 Introduction

1.1 Historic development

The earth is composed of various materials. Materials science and engineering serves as the base for all technology branches such as electronics, energy, communication, environment, and health engineering. Construction materials are the most widely used materials and their usage is the largest in terms of tonnage in the world.

Through the history of human civilization, many materials such as clay, brick, rock, concrete, wood and steel have been used in the construction of buildings, bridges, roads and other structures. According to their load-carrying function in structures, construction materials can be divided into structural materials and non-structural materials. Structural materials carry not only their own self-weight, but also loads being transferred from other components of buildings or infrastructures. On the other hand, non-structural materials only carry their own weight. Non-structural materials include floor and wall coverings, tiles, glass, insulation materials, sealants and paint or coatings. Most of them are specified for protection, aesthetic and architectural purposes by the architect or the interior designer.

The focus of this book is on modern structural materials including concrete, steel, wood, bituminous materials as well as polymers and fibrous composites. Among these materials, concrete will receive the most attention for two reasons. First, the civil engineer is responsible for designing the concrete he/she uses and for ensuring its long term performance. It should be pointed out that steel and wood products are designed by material and mechanical engineers, who supply them to civil engineers according to their specifications. Second, concrete (reinforced concrete) is the most widely-used construction material in the world.

Besides concrete, steel and wood are the other two most commonly-used construction materials in the world. In the US, for example, most residential houses are built with wood and over half of the office buildings are constructed with steel. This is due to the abundant supply of both materials, making them economical. Steel, besides its use as structural members on its own, is also used as reinforcements or prestressed tendons for concrete structures. Understanding steel behavior is hence an important component in the study of reinforced concrete and prestressed concrete design. Bituminous materials are used all over the world in the construction of road pavements. In recent years, polymers and

polymeric composites have been gaining popularity in the construction industry, due to their light weight and good durability. Polymers have been used in pipes, fabrics for roofing as well as geotextiles for slope protection. Reinforcing bars and grids have been made with fiber reinforced composites to replace metals in corrosive environments. Moreover, structural renovation in concrete utilizes more and more fibrous composites.

Soil is also an important construction material. Masonry (bricks and blocks) are widely used in building walls. Since they are not the primary load carrying components, they are not discussed in this book.

1.2 Structural materials and structural design

Structural materials and structural design are two closely related fields and have mutual influence on each other. To design a building or a bridge, we often start with a given structural form based on an architectural design. Once the loading on the structure is determined, structural analysis allows us to obtain the axial forces, moments and shear forces in each of the members. In this stage, materials properties are only needed for statically indeterminate structures (structures with redundant restraints). We then choose member sizes to ensure that failure or excessive deflection will not occur. Moreover, in case failure occurs, we want it to be gradual, rather than sudden and without warning. In order to perform this task, two issues need to be addressed. First, how can one relate the maximum stress and deflection of a member to the applied moment and shear as well as the member size and material stiffness. This issue involves materials properties and theories in

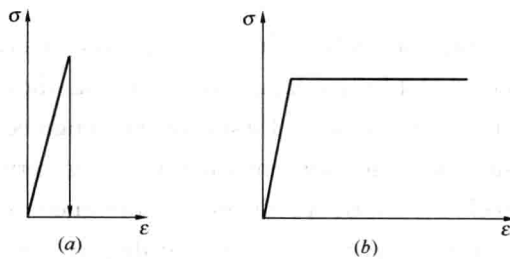


Figure 1-1 Stress-Strain Diagrams

(a) Brittle; (b) Ductile Materials

the mechanics of materials. Second, what is the strength (or maximum stress capacity) and stiffness of the material, and what is its failure mode. This involves the study of the behavior of structural materials, and is best presented in terms of the stress-strain diagram (or constitutive relation) of the material (Figure 1-1).

Figure 1-1 shows the stress-strain relationship for typical brittle and ductile materials. The stress is obtained by dividing the force by the area it acts on ($\sigma = \frac{F}{A}$) and the strain is obtained by dividing the elongation to its original length ($\epsilon = \frac{\Delta l}{l_0}$). The initial slope of the stress-strain diagram reflects the stiffness of the material. The higher the slope, the more difficult it is to deform the material. If a structural member is made with a stiffer material, its deflection will be reduced. Figure 1-1(a) shows the stress-strain relation for a brittle material such as glass.

Once a critical stress value (the strength) is reached, failure will occur suddenly with no warning. The stress-strain relation shown in Figure 1-1(b) represents that of mild steel (up to a certain strain level). After the yield value is reached, the material can still carry stress on further deformation. This deformation capability is called ductility. The implication is that the structural member will undergo significant deflection before failure occurs, providing a warning to people in and around the structure.

In the above discussion, we start with the structure form, and then consider the relevance of the material stress-strain relation in choosing the member size. In reality, the stress-strain relation of a material often determines the structural form. For example, due to the high compressive strength but low tensile strength of natural stone, historical stone bridges are built in the arch form. With the development of high strength steel, cable suspended and cable stayed bridges can be designed. The fact that structural form is affected by material behaviour is usually taken for granted, since we have sufficient experience with materials like concrete, wood and steel to prescribe the structural form. When new materials (such as fiber reinforced composites) are introduced, civil engineers need to come up with new structural forms which take full advantage of the materials.

In recent years, due to the infrastructure decay problem in many developed countries, the long term performance of structures has become an important concern. In other words, we are interested in knowing how the stress-strain relation may change with time. For example, under chemical attack and repeated loading from traffic, would the strength of concrete or steel be reduced over time? Under sustained loading over many years, would the stiffness of polymers become much lower, hence leading to excessive deflection? These are important issues to be addressed and are some of the major foci of discussion throughout the course.

Mechanical properties of various materials, including strength, stress, strain, elastic modulus, viscosity, creep, shrinkage etc, are present in chapter 2. Besides the mechanical properties, physical properties and chemical properties of construction materials are also important. For instance, the weight of the materials governs the dead load on a structure. Its porosity governs water and gas penetration that affects material durability. The chemical properties govern the likelihood of chemical reaction and deterioration under various environments, and are clearly important in the study of the long term performance of materials.

1.3 Physical properties

Physical properties are properties of matter that can be observed without changing the chemical composition. The physical properties of matter may include, but are not limited to, color, density, porosity, conductivity, ductility, brittleness, dielectrics, melting point, permeability, specific heat, resistivity, viscosity, thermal expansion, texture, etc.

In this section, the following physical properties of substance are of concerned;