REVIEW OF LITERATURE

CHAPTER II

REVIEW OF LITERATURE

There is an abundant amount of literature available on building materials used in masonry, framework, main structure, furnishings, upholsteries, etc. In this chapter literature which is most relevant, contemporary and applicable has been summarized under following heads:

2.1 Organic building materials

2.2 Environmental factors affecting indoor housing conditions

2.3 Review of studies in India and abroad:

a. Organic building materials

b. Housing and human performance

2.1 Theoretical Review on Organic Building Materials

A brief description of organic building materials used in building construction on the basis of various studies quoted by Dietz, Harper, Detroit, Wood Handbook by U.S. Government, Modern Plastic Encyclopedia cited in Merrit; 1986, is given below:

a. WOOD

Wood is a natural polymer composed of cells in the shape of long thin tubes with tapered ends. The cell wall consists of crystalline cellulose aligned parallel to the axis of the cell. Typical natural cellulose has several thousands $C_6H_{10}O_5$ molecular units in each chain. The cellulose crystals are bonded together by a complex amorphous lignin composed of carbohydrate compounds. Wood substances are 50 to 60% cellulose and 20 to 35% lignin, the remainder being other carbohydrates and mineral matter. There are different varieties of wood used in construction (Plate-1)

Plate 1: Types of wood used in building constructions

i. Types of Wood

- **Diffuse-porous wood**

Certain hardwoods in which the pores tend to be uniformly sized and distributed throughout each annual ring or to decrease in size slightly and gradually toward the outer border of the ring

- **Earlywood**

Portion of the annual growth ring that is formed during the early part of the growing season; it is usually less dense and mechanically weaker than latewood

- **Hardwoods**

General botanical group of trees that has broad leaves in contrast to the conifers or soft wood.

- **Latewood**

Portion of the annual growth ring that is formed after the early wood formation has ceased; it is usually denser and mechanically stronger than early wood.

- **Lumber**

Product of the saw and planing mill manufactured from a log through the process of sawing, resawing to width, passing lengthwise through a standard planing machine, and crosscutting to length.

- **Ring-porous woods**

Group of hardwoods in which the pores are comparatively large at the beginning of each annual ring and decrease in size more or less abruptly toward the outer portion of the ring, thus forming a distinct inner zone of pores, the early wood, and an outer zone with smaller pores, the latewood

- **Softwoods**

General botanical group of trees that in most cases has needlelike or scale like leaves (the conifers); term has no reference to the actual hardness of the wood. Wood is an extremely versatile material with a wide range of physical and mechanical properties among the many species of wood. It is also a renewable resource with an exceptional strength-to-weight ratio. Wood is a desirable construction material because the energy requirements of wood for producing a usable end-product are much lower than those of competitive materials, such as steel, concrete, or plastic.

ii. Structure of Wood

The anatomical structure of wood affects strength properties, appearance, resistance to penetration by water and chemicals, resistance to decay, pulp quality, and the chemical reactivity of wood. To use wood most effectively requires knowledge of not only the amounts of various substances that make up wood, but also how those substances are distributed in the cell walls. Woods are either hardwoods or softwoods. Hardwood trees (angiosperms, ie, plants with covered seeds) generally have broad leaves, are deciduous in the temperate regions of the world, and are porous, ie, they contain vessel elements. Softwood trees (conifers or gymnosperm, ie, plants with naked seeds) are cone bearing, generally have scale like or needlelike leaves, and are nonporous, ie, they do not contain vessel elements. The terms hardwood and softwood have no direct relation to the hardness or softness of the wood. In fact, hardwood trees such as cottonwood, aspen, and balsa have softer wood than the western white pines and true firs; certain softwoods, such as longleaf pine and Douglas-fir, produce wood that is much harder than that of basswood or yellow-poplar. Many mechanical properties of wood, such as bending and crushing strength and hardness, depend upon the density of wood; denser woods are generally stronger (6). Wood density is determined largely by the relative thickness of the cell wall and by the proportions of thick-walled and thin-walled cells present. The cells that make up the structural elements of wood are of various sizes and shapes and are firmly bonded together. Dry wood cells may be empty or partly filled with deposits such as gums, resins, or other extraneous substances. Long and pointed cells, known as fibers or tracheids, vary greatly in length within a tree and from species to species. Hardwood fibers are ~1 mm long, and softwood fibers are ~3 to 8 mm. Just under the bark of a tree is a thin layer of cells, not visible to the naked eye, called the cambium. Here, cells divide and eventually differentiate to form bark tissue outside of the cambium and wood or xylem tissue inside of the cambium. This newly formed wood on the inside contains many living cells and conducts sap upward in the tree, and hence, is called sapwood. Eventually, the inner sapwood cells become inactive and are transformed into heartwood. This transformation is often accompanied by the formation of extractives that darken the wood, make it less porous, and sometimes provide more resistance to decay. Because of the great structural variations in wood, there are many possibilities for selecting a species for a specific purpose. Some species, like spruce, combine light weight with relatively high values for stiffness and bending strength. Very heavy woods, like lignum vitae, are extremely hard and resistant to abrasion. A very light wood, like balsa, has high thermal insulation value. Hickory has extremely high shock resistance. Mahogany has excellent dimensional stability.

iii. Wood properties

- **Physical Properties**

Physical properties are the quantitative characteristics of wood and its behavior to external influences other than applied forces. Included here are directional properties, moisture content, dimensional stability, thermal and pyrolytic (fire) properties, density, and electrical, chemical, and decay resistance. Familiarity with physical properties is important because they can significantly influence the performance and strength of wood used in structural applications. The physical properties of wood most relevant to structural design and performance are discussed in this section.

Dimensional Stability: Above the fiber saturation point, wood will not shrink or swell from changes in moisture content because free water is found only in the cell cavity and is not associated within the cell walls. However, wood changes in dimension as moisture content varies below the fiber saturation point. Wood shrinks as it loses moisture below the fiber saturation point and swells as it gains moisture up to the fiber saturation point. These dimensional changes may result in splitting, checking, and warping. The phenomena of dimensional stability and EMC must be understood, Dimensional stability of wood is one of the few properties that significantly differs in each of the three axis directions. Dimensional changes in the longitudinal direction between the fiber saturation point and oven dry are between 0.1 and 0.2% and are of no practical significance; however, in reaction or juvenile wood, these percentages may be significantly higher. The combined effects of shrinkage in the tangential and radial axes can distort the shape of wood pieces because of the difference in shrinkage and the curvature of the annual rings. Generally, tangential shrinkage (varying from 4.4 to 7.8% depending on species) is twice that of radial shrinkage (from 2.2 to5.6%).

Thermal Expansion: Thermal expansion of dry wood is positive in all directions; wood expands when heated and contracts when cooled. Wood that contains moisture reacts to temperature changes differently than dry wood. The linear expansion coefficients of dry wood parallel to grain are generally independent of specific gravity and species and range from approximately 3 x 10-6 to 4.5 x 10-6 per ^{0}C. The linear expansion coefficients across the grain (tangential and radial) are in proportion to density and range from approximately 5 to 10 times greater than parallel to grain coefficients. When moist wood is heated, it tends to expand because of normal thermal expansion and shrink because of moisture loss from increased temperature. Unless the initial moisture content of the wood is very low (3 to *4%)*, the net dimensional change on heating is negative. Wood at intermediate moisture contents of approximately 8 to 20% will expand when first heated, then gradually shrink to a volume smaller than the initial volume as moisture is lost in the heated condition.

Electrical Resistance: Wood is a good electrical insulator. However, significant variations in conductivity do exist. These variations in electrical resistance can be related to variations in grain orientation, temperature, and moisture content. The conductivity of wood in the longitudinal axis is approximately twice that in the radial or tangential axes. The electrical conductivity of wood generally doubles for each 10 ^{0}C increase in temperature. Generally, variations in conductivity related to wood density and species are considered minor. The correlation between electrical resistivity and moisture content is the basis for electrical resistance type moisture meters that estimate moisture content by measuring the resistance of the wood between two electrodes. Moisture content meters, as these instruments are commonly called, need to be calibrated for temperature and species and are effective only for moisture content ranges of 5 to *25%.* They are generally unreliable for high resistivities at moisture contents below 5 or 6%, for estimating the moisture content of green timber, or for estimating moisture content of treated timbers (most treatments alter conductivity).

Decay Resistance: Wood decay fungi and wood-destroying organisms require oxygen, appropriate temperature, moisture, and a food source. Wood will not decay if kept dry (moisture content less than 20%). On the other extreme, if continuously submerged in water at sufficient depths. Wood will usually not decay. Whenever wood is intermediary to either of these two extremes, problems with wood decay can result. To avoid problems with decay where moisture cannot be controlled, the engineer or designer can use either naturally durable species or treated timber. The natural durability of wood to the mechanisms and processes of deterioration is related to the anatomical characteristics and species of wood. In general, the outer zone or sapwood of all species has little resistance to deterioration and fails rapidly in adverse environments. For heartwood, natural durability depends on species. Heartwood forms as the living sapwood cells gradually die. In some species, the sugars present in the cells are converted to highly toxic extractives that are deposited in the wood cell wall. Many species produce durable heartwood, including western red cedar, redwood, and black locust; however, durability varies within a tree and between trees of a given species. To enhance durability, wood can be treated with an EPA-registered, toxic preservative chemical treatment.

Chemical Resistance: Wood is highly resistant to many chemicals, which gives it a significant advantage over many alternative building materials. Wood is often considered superior to alternative materials, such as concrete and steel, partly because of its resistance to mild acids (pH more than 2.0), acidic salt solutions, and corrosive agents. Generally, iron holds up better on exposure to alkaline solution than does wood, but wood can be treated with many of the common wood preservatives (e. g., creosote) to greatly enhance its performance in this respect.

Heartwood is far more durable than sapwood to chemical attack because heartwood is more resistant to penetration by liquids. Many preservative treatments, such as creosote or pentachlorophenol in heavy oil, can also significantly increase the ability of wood to resist liquid or chemical penetration, or both. Chemical solutions may induce two general types of action: normal reversible swelling by a liquid and irreversible chemical degradation. With the former, removal of the liquid will return wood to its original condition. With the latter, permanent changes occur within the wood structure from hydrolysis, oxidation, or delignification.

- **Mechanical Properties**

Mechanical properties are the characteristics of a material in response to externally applied forces. They include elastic properties, which characterize resistance to deformation and distortion, and strength properties, which characterize resistance to applied loads. Mechanical property values are given in terms of stress (force per unit area) and strain (deformation resulting from the applied stress). The mechanical property values of wood are obtained from laboratory tests of lumber of straight-grained clear wood samples (without natural defects that would reduce strength, such as knots, checks, splits, etc.).

Shear: When used as a beam, wood is exposed to compression stress on one surface of the beam and tensile stress on the other. This opposition of stress results in a shearing action through the section of the beam. This parallel-to-grain shearing action is termed horizontal shear. The horizontal shear strength of clear Douglas-fir and loblolly pine averages 6.2 and 5.9 MPa, respectively. Conversely, when stress is applied perpendicular to the cell length in a plane parallel to grain, this action is termed rolling shear. Rolling shear stresses produce a tendency for the wood cells to roll over one another. In general, rolling shear strength values for clear specimens average 18 to 28% of the parallel-to-grain shear values.

Energy Absorption Resistance: Energy absorption or shock resistance is a function of the ability of a material to quickly absorb and then dissipate energy via deformation. Wood is remarkably resilient in this respect and is often a preferred material for shock loading. Several parameters are used to describe energy absorption depending on the eventual criteria of failure considered. Work to proportional limit, work to maximum load, and work to total failure (i. e., toughness) describe the energy absorption of wood materials at progressively more severe failure criteria.

Fatigue: The fatigue resistance of wood is sometimes an important consideration. Wood, like many fibrous materials, is quite resistant to fatigue

(i. e., the effects of repeated loading). In many crystalline metals, repeated loadings of 1 to 10 million cycles at stress levels of 10 to 15%. of ultimate can induce fatigue type failures. At comparable stress levels, the fatigue strength of wood is often several times that of most metals.

Hardness: Hardness represents the resistance of wood to indentation and marring. Hardness is comparatively measured by force required to embed a 11.3-mm ball one-half its diameter into the wood.

- **Environmental Properties**

Moisture Content: Mechanical property values of wood increase as wood dries from the fiber saturation point to 10 to 15% moisture content. For clear wood, mechanical property values continue to increase as wood dries below 10 to 15% moisture content. For lumber, studies have shown that mechanical property values reach a maximum at about 10 to 15% moisture content. Then begin to decrease with decreasing moisture content below 10 to 15%. For either product, the effects of moisture content are considered to be reversible in the absence of decay.

Temperature: Strength and stiffness decrease when wood is heated and increase when cooled. The temperature effect is immediate and, for the most part, reversible for short heating durations. However, if wood is exposed to elevated temperatures for an extended time, strength is permanently reduced because of wood substance degradation and a corresponding loss in weight. The magnitude of these permanent effects depends on moisture content, heating medium, temperature, exposure period, and to a lesser extent, species and specimen size. As a general rule, wood should not be exposed to temperatures above 65OC. The immediate effect of temperature interacts with the effect of moisture content so that neither effect can be completely understood without consideration of the other.

Decay and Insect Damage: Wood is conducive to decay and insect damage in moist, warm conditions. Decay within a structure cannot be tolerated because strength is rapidly reduced in even the early stages of decay. It has been estimated that a 5% weight loss from decay can result in strength losses as high as 50%. If the warm, moist conditions required for decay cannot be controlled, then the use of naturally decay resistant wood species or chemical treatments are required to impede decay. Insects, such as termites and certain types of beetles, can be just as damaging to mechanical performance. Insect infestation can be controlled via mechanical barriers, naturally durable species, or chemical treatments.

Reaction to Heat and Fire: The physical and chemical properties of wood, like those of any organic material, are subject to deterioration. The rate and extent of deterioration are governed by the interdependent factors of temperature, time, and moisture. In locations not conducive to decay or insect attack, wood is extremely stable at ordinary temperatures. However, with increasing temperature, the degradation of surface layers progresses into the interior layers. Prolonged heating at temperatures as low as 90°C may cause charring. In general, the thermal degradation of wood and other cellulosic substances proceeds along one of two competing reaction pathways (28). At temperatures up to ~200°C, carbon dioxide and traces of organic compounds are formed, in addition to the release of water vapor. The gases are not readily ignitable, but under certain conditions, a pilot flame can ignite the volatiles after 14 to 30 min at 10°C (29). Exothermic reactions may occur near 200°C and, in situations where heat is conserved, self-ignition at temperatures as low as 100°C has been observed (30). Times and temperatures that might result in smoldering initiation can be determined (31). To provide a margin of safety, 77°C should be the upper limit in prolonged exposure near heating devices. Temperatures in excess of 200°C lead to much more rapid decomposition. Under these conditions, the pyrolysis gases contain 200 or more different components (32-34) and the degradation is accompanied by reduction in weight, depending on temperature and duration of heating (35) (Fig. 11). Thermo-gravimetric analysis of wood [a -cellulose and lignin (Fig. 12)] indicates that a slow initial weight loss for lignin and wood begins at ~200°C. Differential thermal analyses (delta) of wood and its components indicate that the thermal degradation reactions in an inert atmosphere release less than 5% of the heat released during combustion in air.

Wood in its untreated form has good resistance or endurance to fire penetration when used in thick sections for walls, doors, floors, ceilings, beams, and Fire retardant chemicals, such as ammonium phosphate, ammonium sulfate, zinc chloride, guanylurea phosphate, dicyandiamide phosphate, borax, and boric acid, are often used in combinations. Borax and boric acid mixtures are moderately effective in reducing flamespread and afterglow without premature charring during severe drying operations. Although very hydroscopic, zinc chloride is an effective flame retardant; boric acid is often added to retard afterglow. Fire retardant treatments can adversely affect the strength properties of wood. Elevated temperatures in service can cause futher strength loss (52). Fire retardants such as ammonium sulfate can have a corrosive effect on metal fasteners. In exterior applications, a treatment with resistance to weathering and leaching is important (53,54). Solutions of these fire retardant formulations are impregnated into wood under full cell pressure treatment to obtain dry chemical retentions of 65 to 95 kg/m3; this type of treatment greatly reduces flame-spread and afterglow. These effects are the result of changed thermal decomposition reactions that favor production of carbon dioxide and water (vapor) as opposed to more flammable components (55). Char oxidation (glowing or smoldering) is also inhibited. Some of the chemicals mentioned above and others, such as chlorinated rubber or paraffin, antimony trioxide, calcium carbonate, calcium borate, pentaerythrithol, alumina trihydrate, titanium dioxide, and urea-melamineformaldehyde resin, may be used to formulate fire retardant coatings. Many of these coatings are formulated in such a way that the films intumesce (expand) when exposed to fire, thus insulating the wood surface from further thermal exposure. Fire retardant coatings are mostly used for existing construction.

Resistance to Chemicals: Different species of wood vary in their resistance to chemical attack. The significant properties are believed to be inherent to the wood structure, which governs the rate of ingress of the chemical and the composition of the cell wall, which affects the rate of action at the point of contact (56). Wood is widely used as a structural material in the chemical industry because it is resistant to a large variety of chemicals. Its resistance to mild acids is far superior to that of steel but not as good as some of the more expensive acid-resistant alloys. Wood tanks used to store cold, dilute acid have a relatively long service life. However, increasing concentration or temperature causes the wood tank to deteriorate rapidly (6). Softwoods are generally more resistant to acids than are hardwoods because they have high lignin and low hemicellulose contents. In general, heartwood is more resistant to acids than sapwood, probably because of heartwood's higher extractive content and slower movement of liquid into the heartwood. For these reasons, the heartwood of certain conifers has been widely used in the chemical industry. Oxidizing acids, such as nitric acid, attack wood faster than common mineral acids, although wood is frequently used in contact with dilute nitric acid. Oxidizing acids not only attack wood by hydrolysis of the polysaccharides but also degrade these polymers through oxidative reaction. Wood shows excellent resistance to organic acids, which gives it a distinct advantage compared with steel, concrete, rubber, and some plastics. Mild organic acids such as acetic acid have little effect on wood strength.

Alkaline solutions attack wood more rapidly than acids of equivalent concentrations, whereas strong oxidizing chemicals are harmful. Wood is seldom used where resistance to chlorine and hypochlorite solutions is required. These chemicals cause extensive degradation of cell wall polymers. Wood tanks are, however, satisfactory for holding hydrogen peroxide solutions and give good service on contact with strong brine. Solutions of iron salts cause degradation, particularly of the polysaccharides.

In contact with iron under damp conditions, wood may show severe deterioration within a few years. Species high in acidic extractives seem especially prone to such attack. Because traces of iron reduce the brilliance of many dyes, wood tanks have long been preferred to steel in the manufacture of dyes. Similarly, vinegar and sour foodstuffs are processed in wood tanks because common metals impart a metallic taste. Ease of fabrication may be the reason for using wood tanks in less accessible areas to which ready-made tanks of other materials cannot be easily moved.

Resistance to chemical attack is generally improved by resin impregnation, which protects the underlying wood and reduces movement of liquid into the wood. Resistance to acids can be obtained by impregnating with phenolic resin and to alkalies by impregnating with furfural resin.

Biodeterioration: The principal organisms that degrade wood are fungi, bacteria, insects, and marine borers. Decay, molds, and stain are caused by fungi. Decay is the most serious kind of damage because it causes structural failure and consequently, tremendous economic losses. Soft rot is another type of decay that weakens wood, but it typically progresses slowly and is most often associated with very wet wood. Moisture conditions conducive to decay occur when the moisture content of the wood is above fiber saturation (~30%). The optimum temperature range for most decay fungi is about 25-30°"C, although some species grow at temperatures as low as 0°C and some as high as 45°C. The optimum pH is in the range of 4.5 to 5.5. Oxygen is essential for growth of all species. Decay can be prevented by keeping wood either too dry (below 20% moisture content) or too wet (lumens filled with water) for fungal development, by using naturally decay-resistant species, or by treating with preservatives. Mold and stain fungi primarily attack the sapwood. Mold fungi growth occurs primarily on the surface of the wood, while stain fungi may cause a stain throughout the affected sapwood. These fungi can be controlled by dipping the lumber in a fungicidal solution immediately after cutting. Bacterial degradation of wood generally is not a serious problem, although in some situations of extreme wetness, bacteria may increase the permeability of wood after many years or reduce the strength of the wood.

Termites are the most destructive insects that attack wood. Their attack can be prevented or lessened by using naturally resistant wood or by treating wood with preservatives. For subterranean termites, which generally require contact with the ground to survive, poisoning the soil around the wood structure is the principal means of preventing infestation. A promising new approach to subterranean termite control is the use of food bait with an insecticide. The dry wood termite flies directly to the wood, bores into it, and does not require contact with the ground. Physical barriers, such as paint or screens, prevent infestation. Despite great differences between fungi and termites, chemicals that inhibit fungi usually also inhibit termites.

Marine borers inhabit saline or brackish waters where they cause serious destruction to untreated wood. The mollusks include the Teredo and Bankia borers; among the crustaceans, the Limnoria borers are the most widespread and destructive. Preservatives or borer-resistant woods deter marine borers. For practical purposes, the sapwood of all species may be considered to be susceptible to bio-deterioration. The heartwood of some species, however, contains toxic extractives that protect it against biological attack. Among the native species that have decay-resistant or highly decay-resistant heartwood are bald cypress, redwood, cedars, white oak, black locust, and black walnut. Douglasfir, several of the pines, the larches, and honey locust are of intermediate decay resistance. Species low in decay resistance include the remainder of the pines, the spruces, true firs, ashes, aspens, birches, maples, hickories, red and black oaks, tupelo, and yellow poplar. Native woods considered somewhat resistant to termite attack include close-grained redwood heartwood and resinous heartwood of southern pine. Although several tropical woods show resistance to marine borers, no commercial native woods are sufficiently borer resistant to be used untreated.

The best protection for wood against the attack of decay fungi, insects, or marine borers is obtained by applying preservatives under pressure before installation. Both oil-type preservatives, such as creosote or petroleum solutions of pentachlorophenol, and waterborne preservatives, such as copper chrome arsenate and ammoniacal-copper arsenate, are used when wood is to be in direct contact with the ground or in the marine environments. Where wood is to be used under low to moderate decay hazard conditions (eg, above ground), it can be protected by brushing, spraying, dipping, or steeping. Once decay is established, preservatives brushed onto the wood will not penetrate, and decay cannot be eradicated in this way. However, high vapor pressure fungicides (fumigants) penetrate deeply into wood and have successfully stopped internal decay in structural timbers. Diffusible preservatives such as boron and fluoride are also used to eradicate decay.

b. PLYWOOD

Plywood is made by bonding together a number of thin sheets or veneers of wood. The grain in adjacent plies is oriented at right angles, and an odd number of plies are used. The main purpose of plywood is to over come the directional properties of wood, thereby obtaining a material more uniform in all directions. Plywood shows greater resistance to checking and splitting than lumber and has better dimensional stability because of reduced shrinkage and swelling. It is classed as interior or exterior depending on the type of adhesive used to bond the plies together. Interior grade usually is bonded with water soluble glues and thus has limited resistance to moisture. Exterior grade is completely waterproof in that it can withstand prolonged immersion in water without disintegration.

c. CELLULOSE DERIVATIVES

Cellulose is a naturally occurring high polymer found in all woody plant tissue and in such materials as cotton. It can be modified by chemical processes in to a variety of thermoplastic materials, which in turn may be still further modified with plasticizers, fillers, and other additives to provide a wide variety of properties. The oldest of all plastics is cellulose nitrate.

i. Cellulose Acetate: It is the basis of safety film, developed to overcome the highly flammable nature of cellulose nitrate. Starting as film, sheet, or molding powder, it is made into a variety of items, such as transparent package and a large variety of general purpose items. Depending on the plasticizer content, it may be hard and rigid or soft and flexible. Moisture absorption of this and all other cellulosics is relatively high and they are therefore not recommended for long continued outdoor exposure. But cellulose acetate film, reinforced with metal mesh, is widely used for temporary enclosures of buildings during construction.

ii. Cellulose Acetate Butyrate: It is a butyrate polymer, is inherently softer and more flexible than cellulose acetate and requires less plasticizer to achieve a given degree of softness and flexibility. It is made in the form of clear transparent sheets and film or in the form of molding powders which can be molded by standard injection molding procedures in to a wide variety of products. Like the other cellulosics, this material is inherently tough and has good impact resistance. It has infinite colorability, like the other cellulosics. Cellulose acetate butyrate tubing is used for such application as irrigation and gas lines.

iii. Ethyl Cellulose: It is similar to cellulose acetate and acetate butyrate in its general properties. Two varieties, general purpose and high impact are common, high impact ethyl cellulose is made for better than average toughness at normal and low temperatures.

iv. Cellulose Nitrate: It is one of the toughest plastics, is widely used for tools handles and similar applications requiring high impact strength. Its high flammability requires great caution, particularly when the plastics in the form of film. Most commercial photographic films are made of cellulose nitrates rather than safety film. Cellulose nitrate is the basis of most of the widely used commercial lacquers for furniture and similar items.

d. PLASTICS

The synonymous terms plastics and synthetic resins denote synthetic organic high polymers are compounds in which the basic molecular level subunits are long chain molecules. The word of plastic has been adopted as a general name for the group of materials because all are capable of being molded at some stage in their manufacture. The mechanical behaviour of a plastic is generally affected the internal structure of the polymer. The elastic moduli of plastics generally range from 10^4 to 10^6 psi, considerably lower than for metals. The greater strains observed when plastics are loaded result from the fact that there is chain straightening in polymers as well as bond lengthening. Permanent deformation in plastics occurs as slip between adjacent molecular chains. Plastics are divided into two large categories based on their thermal behaviour: thermoplastic and thermosetting materials.

i. Thermoplastic Materials: These material extremely plastic, that is, easily deformable, at elevated temperatures. They become hard again on cooling. They can be so softened by heating and hardened by cooling any number of times. Thermoplastic resins deform easily under applied pressures, particularly at elevated temperatures and so are used to make molded products. Materials in this category can be repeatedly softened by heating and hardened by cooling. The main varieties of thermoplastics are as following:

- **Acrylics:** Acrylics in the form of large transparent sheets are used in aircraft enclosures and building constructions. Although not so hard as glass, acrylics have perfect clarity and transparency. They are the most resistant of the plastics to sunlight and outdoor weathering and they have an optimum combination of flexibility and rigidity with resistance to shattering. Sheets of acrylic are readily formed to complex shapes. They are used for such applications as transparent windows, outdoors and indoors signs, parts of lighting equipments, decorative and functional automotive parts, reflectors, household appliances parts and similar applications.

- **Acryl–Butadienenitril-Sryrene (Abs):** ABS is a three way copolymer that provides a family of tough, hard, chemically resistant resins. The greatest use is for pipes and fittings.

- **Polycarbonate:** It has excellent transparency, high resistance to impact and good resistance to weathering. It is used for safety glazing, general illumination and hard hats.

- **Polyethelene:** In its unmodified form is a flexible, waxy, translucent plastic maintaining flexibility at very low temperatures in contrast with many other thermoplastic materials. It is highly inert to most solvents and corrosive chemicals of all kinds at ordinary temperatures. It is widely used as a primary insulating material on wire and cable and has been used also as replacement for the lead jacket on communication cables and other cables.

- **Polypropylene:** It is a polyolefin, is similar in many ways to its counterpart, polyethylene, but is generally harder, stronger and more temperature resistant. It has a great many uses among them for complete water cisterns for water closets in plumbing systems abroad.

- **Polytetrafluoroethylene:** Polytetrafluoroethylene, with the very active element fluorine in its structure, is a highly crystalline linear type polymer, unique among organic compounds in its chemical inertness and resistance to change at high and low temperatures. This material is not embrittled at low temperatures and its films remain flexible at temperatures below 100^0F. It is used in bridges as beam seats or bearings and in buildings calling for resistance to extreme conditions, or for applications requiring low friction. In steam lines, for example, supporting pads of Polytetrafluoroethylene permit the line to slide easily over the pads as expansion and contraction with changes in temperature cause the line to lengthen and shorten. The temperatures involved have little or no effect.

- **Polyvinyl Fluoride:** It has much of the superior inertness to chemical and weathering attack typical of the fluorocarbons. Among other uses, it is used as thin-film overlays for building boards to be exposed outdoors.

- **Polyvinyl Formal Resins:** Polyvinyl resins are used principally as a base for tough, water-resistant insulating enamel for electric wire.

- **Polyvinyl Butyral:** It is the tough interlayer in safety glass. In its cross-linked and plasticized form, polyvinyl butyral is used extensively in coating fabrics for raincoats, upholstery and other heavy duty moisture-resistant applications.

- **Vinyl Chloride Polymers and Copolymers:** They vary from hard and rigid to highly flexible. Polyvinyl chloride is naturally hard and rigid but can be plasticized to any required degree of flexibility, as in raincoats and shower curtains. Copolymers including vinyl chloride plus vinyl acetate are naturally flexible without plasticizers. Non rigid vinyl plastics are widely used as insulation and jacketing for electric wire and cable because of their electrical properties and resistance to oil and water. Heavy gauge sheets are widely used as upholstery. Vinyl chlorides are used for floor coverings in the form of tile and sheet because of their abrasion resistance and relatively low water absorption. The rigid materials are used for tubing, pipe and other applications which require resistance to corrosion and action of many chemicals, especially acids and alkalis; they are attacked by a variety of organic solvents.

- **Vinylidene Chloride:** It is highly resistant to most inorganic chemicals and organic solvents generally. It is impervious to water on prolonged immersion and its films are highly resistant to moisture-vapour transmission. It can be sterilized. It is not recommended for uses involving high speed impact, shock resistance or flexibility at subfreezing temperatures. It should not be used in applications requiring continuous exposure to temperatures in excess of 170^0F.

- **Polystyrene Formulations:** They constitute a large and important segment of the entire field of thermoplastic materials. It is one of the lightest of the presently available commercial plastics. It is relatively inexpensive and easily molded and has good dimensional stability and good stability at low temperatures. It is brilliantly clear when transparent but can be produced in an infinite range of colors. Water absorption is negligible even after long immersion. Electrical characteristics are excellent. It is resistant to most corrosive chemicals, such as acids and a variety of organic solvents although it is attacked by others. Under certain circumstances they tend to develop fine cracks, known as craze marks in highly stressed conditions.

- **Polyimide:** Polyimide, in molded form, is used in increasing quantities for impact and high resistance to abrasion. It is employed in small gears, cams, and other machine parts because even when unlubricated, polyimide is highly resistant to wear. Its chemical resistance, except to phenols and mineral acids, is excellent. Extruded polyimide is coated on to electric wire, cable and rope for abrasion resistance.

ii. Thermosetting Materials

These materials are either originally soft at once upon heating but upon further heating they harden permanently. The final, continuous framework structure of thermosetting resins may develop from the condensation polymerization mechanism or may harden by the formation of the primary bonds between molecular chains as thermal energy is applied. In general thermosetting plastics are stronger than thermoplastic resins, particularly at elevated temperatures. Amorphous polymers have a characteristic temperature at which the properties make a drastic change, called the glass transition temperature. The transition from glassy behaviour to rubbery behaviour may occur at any temperature.

- **Phenol Formaldehyde:** It provides the greatest variety of thermosetting molded plastic articles. They are used for chemical decorative, electrical, mechanical and thermal appliances of all kinds. Hard and rigid, they change slightly, if at all, on aging indoors but on outdoor exposure lose their bright surface gloss. However, the outdoor exposure characteristics of the more durable formulations are otherwise generally good. Phenol formaldehyde has good electrical properties, do not burn readily, and do not support combustion. They are strong, light weight and generally pleasant to the eye and touch. Light colors normally are not obtainable because of the dark brown basic color of the resin. They have low water absorption and good resistance to attack by most commonly found chemicals.

- **Furan Resins:** Furan resins are similar to phenolics in many respects. Touch and durable, they have many industrial uses, such as for large aggregate filled molds for shaping light metals.

- **Cast Phenolics:** Cast phenolics were once used in large quantities for brilliantly colored parts, but today they are used principally in industrial applications, including molds.

- **Epoxy and Polyester Resins:** They are used for a variety of purposes. For example, electronic parts with delicate components are sometimes cast completely in these materials to give them complete and continuous support and resistance to thermal and mechanical shock. Some varieties must be cured at elevated temperatures; others can be formulated to be cure at room temperatures. One of the outstanding attributes of the epoxies is their excellent adhesion to a variety of materials, including such metals as copper, brass, steel and aluminum.

- **Polyester Molding Materials:** When compounded with fibers (particularly glass fibers) or with various mineral fibers (including clay), can be formulated into putties or premixes that is easily compression or transfer molded into parts having high impact resistance.

- **Melamine Formaldehyde Materials:** They are unaffected by common organic solvents, grease and oils and most weak acids and alkalis. Their water absorption is low. They are insensitive to heat and are highly flame resistant, depending on the filler. Electrical properties are particularly good, especially resistance to arcing. Unfilled materials are highly translucent and have unlimited colour possibilities. Principle fillers are alpha cellulose for general purpose compounding; minerals to improve electrical properties, particularly at elevated temperatures; chopped fabric to afford high shock resistance and flexural strength; and cellulose, used mainly for electrical purposes.

- **Polyurethane:** It is used several ways in construction. As thermal insulation, it is used in the form of foam; either pre foamed or foamed in place. The latter is particularly useful in irregular spaces. When blown with fluorocarbons, the foam has an exceptionally low λ factor and is therefore widely used in thin walled refrigerators. Others uses include field applied or baked on clear or colored coatings and finishes for floors, walls, furniture and casework generally. The rubbery form is employed for sprayed or troweled on roofing and for gaskets and calking compounds.

- **Alkyds:** Alkyds are customarily combined with mineral or glass fillers, the latter for high impact strength. Extreme rapidly and completeness of cure permit rapid production of large number of parts from relatively few molds. Because electrical properties, especially resistance to arcing, are good, many of the applications for alkyd molding materials are in electrical applications.

- **Urea Formaldehydes:** Urea formaldehydes, kike the melamines, offer unlimited translucent to opaque color possibilities, light fastness, good mechanical and electrical properties and resistance to organic solvents and mild acids and alkalis. Although there is no swelling or change in appearance, the water absorption of urea formaldehyde is relatively high and therefore it is not recommended for applications involving long exposure to water. Occasional exposure to water has no deleterious effect. Strength properties are good.

- **Silicones:** Silicones, unlike other plastics, are based on silicon rather than carbon. As a consequence, their inertness and durability under a wide variety of conditions are outstanding. As compared with the phenolics, their mechanical properties are poor and consequently glass fibers are added. Molding is more difficult than with other thermosetting materials. Unlike most other resins they may be used in continuous operations at 400^0F; they have very low water absorption; their dielectric properties are excellent over an extremely wide variety of chemical attack; and under outdoor conditions their durability is particularly outstanding. In liquid solutions, silicones are used to impart moisture resistance to masonry walls and to fabrics. They also form the basis for a variety of paints and other coatings capable of maintaining flexibility and inertness to attack at high temperatures in the presence of ultra violet sunlight and ozone. Silicone rubbers maintain their flexibility at much lower temperatures than other rubbers.

- **Plasticizers and Fillers:** Plasticizers and fillers may be added to polymers to change their basic properties. Plasticizers are low-molecular-weight (short-chain) substances added to reduce the average molecular weight of a polymer and thus make it more flexible. Fillers may be added, particularly to the softer plastics to stiffen them, increase their strength and impact properties, or improve their resistance to heat. Wood flour, mica, asbestos, fibers and chopped fibers or fabric may be used as filler material for polymers.

e. ASPHALT

Asphalt materials have been known and used in road and building construction since ancient times. Early asphalt was of natural origin, found in pools and asphalt lakes, but current supplies come mainly from the residues of refined petroleum. It is black or dark brown petroleum derivative, is distinct from tar, the residue from destructive distillation of coal. Asphalt consists of hydrocarbons and their derivatives and is completely soluble in carbon disulfide. Asphalt and asphalt products are also used extensively in roofing applications. Asphalt is used as a binder between layers in built up roofing and as the impregnating agent in roofing felts, roll roofing and shingles. Care should be taken not to mix asphalt and tar together, that is, to place asphalt layers on a tar insulated felt or vice versa, unless their compatibility has been checked.

i. Bituminous Pavements: Asphalt refined to meet specifications for paving purposes is called asphalt cement. At normal temperatures it is semisolid. Several types of asphalts are produced as; rapid curing (RC) asphalt, medium curing asphalt and slow curing asphalt and emulsified asphalt.

ii. Asphalt Building Products: It is water resistant and durable therefore, used for many building applications. For damp proofing and water proofing, three types of asphalt are used: Type A, an easy flowing, soft, adhesive material for use underground or in other moderate temperature applications. Type B, a less susceptible asphalt for use above ground where temperatures do not exceed 125+0+F and Type C, for use above ground where exposed on vertical surface to direct sunlight or in other areas where temperatures exceed 125^0F.

It is evident from the above literature that there is a wide variety of organic building materials available. They together make a place to be lived in. Their use in construction is right from civilization of man, but the forms and use of the materials is changing as per the advances in the life.

2.2 Environmental Factors Affecting Indoor Housing Conditions

On the basis of studies of Ashton in 1969; Anonymous (1999); Miral et. al. (2003); Kenjo (2005) and Vadstrup (2005) an interesting fact about the organic building materials was delineated that the durability of materials used in building and subsequently exposed to weather is of great interest to the architects, the builders and the ultimate users. A brief description of the effects of weather on organic building materials classed is given below:

a. WEATHERING

The process of weathering is defined as the action of atmospheric elements in altering the colour, texture, composition or form of exposed objects, ultimately leading to disintegration or failure to perform a function.

Radiation from the sun at the earth's surface is composed of near ultraviolet, visible and near infrared portions of the spectrum. Moisture results from rain (or snow), water vapour (humidity), and condensed water vapour (dew or frost). Thermal aspects of the weather relate to the presence or absence of heat (high or low temperatures) and the rapidity of change from one condition to the other (thermal shock). Gases that can enter into the weathering process directly are the normally present oxygen and carbon dioxide, plus pollutants such as ozone, sulphur dioxide and oxides of nitrogen.

i. Radiation: Organic building materials are chiefly composed of long-chained molecules with carbon-to-carbon backbones. These are attracted to each other by secondary forces, although if the material is "cross-linked" there are also chemical bonds between the long chains. The amount of energy required to break these primary bonds and thus disrupt the individual molecules can be calculated. As the wavelength of radiation decreases, its energy increases and reaches the breaking energy of the carbon bonds at a wavelength of 350 nm. This is well within the range of solar radiation received at sea level. Fortunately, the proportion of shorter wavelength radiation is small at the earth's surface so that the intensity of the most destructive wavelengths is very much reduced. Ultraviolet makes up about 10 per cent of the sun's radiant energy, but at the earth's surface at noon it provides 5 to 7 per cent of the energy; biologically active UV is about one per cent of the total energy. These proportions decrease markedly before and after noon because of atmospheric scattering at lower angles. If this were not the case, no organic material would have any exterior durability.

The degradation of organic building materials attributable to UV can take two paths. With some, the energy starts a process the reverse of the polymerization reaction that produced the large molecules. This is the so-called "unzipping" of the polymer that leads to catastrophic failure. As it is a chain reaction, the aim of materials chemists is to prevent it from starting, a task much easier to state than to accomplish. The inclusion of pigments that reflect the UV or absorb it preferentially to the polymer is the most common remedy; e.g., carbon black in polyethylene. In the other degradation mechanism, the smaller molecules produced by chain scission frequently react across the chains. This results in more cross-linking than was originally present so that the material becomes harder and more brittle. If some flexibility is required for the material to perform its function, the induced brittleness causes cracking. Most organic building materials fail in this manner. On a gross scale, it is called cracking; on a reduced scale, with a rectangular pattern, it is called checking. On plastics, on a small scale, the result is referred to as crazing, while with coatings microscopic cracking leads to chalking as the top layer erodes away.

Even though the organic material itself may be resistant, it is possible for UV light to cause undesirable changes if the material is coloured and the colorant, many of which are organic, is not resistant. Fading, which is usually not acceptable, will occur. UV can also cause yellowing. It may alter a resin's chemical structure so that it absorbs blue visible light and appears to be yellow. Fortunately in many cases visible light has the effect of bleaching these induced colours.

As only short wavelength radiation possesses sufficient energy to break the primary bonds, it follows that longer wavelengths can only directly affect the secondary forces. Visible and infrared radiation lead chiefly to increased temperature and thus to softening in materials that do not contain much cross-linking. The indirect effect is to increase the rate of chemical reactions that may be occurring from other causes. This increase in temperature due to solar radiation can be substantial.

ii. Moisture: Water is one of the most prevalent elements of weather. Because most organic building materials are hydrophobic and not porous, they are not so readily damaged by the freezing action of water as are many inorganic materials. Wood, being composed of a hydrophilic polymer in cellular form is readily swollen by water. The polymer however, does not dissolve in or react with water, so that wood does not disintegrate when swollen, even if later frozen. Water is necessary for the degradation of wood by micro-organisms, even though one type is called "dry" rot.

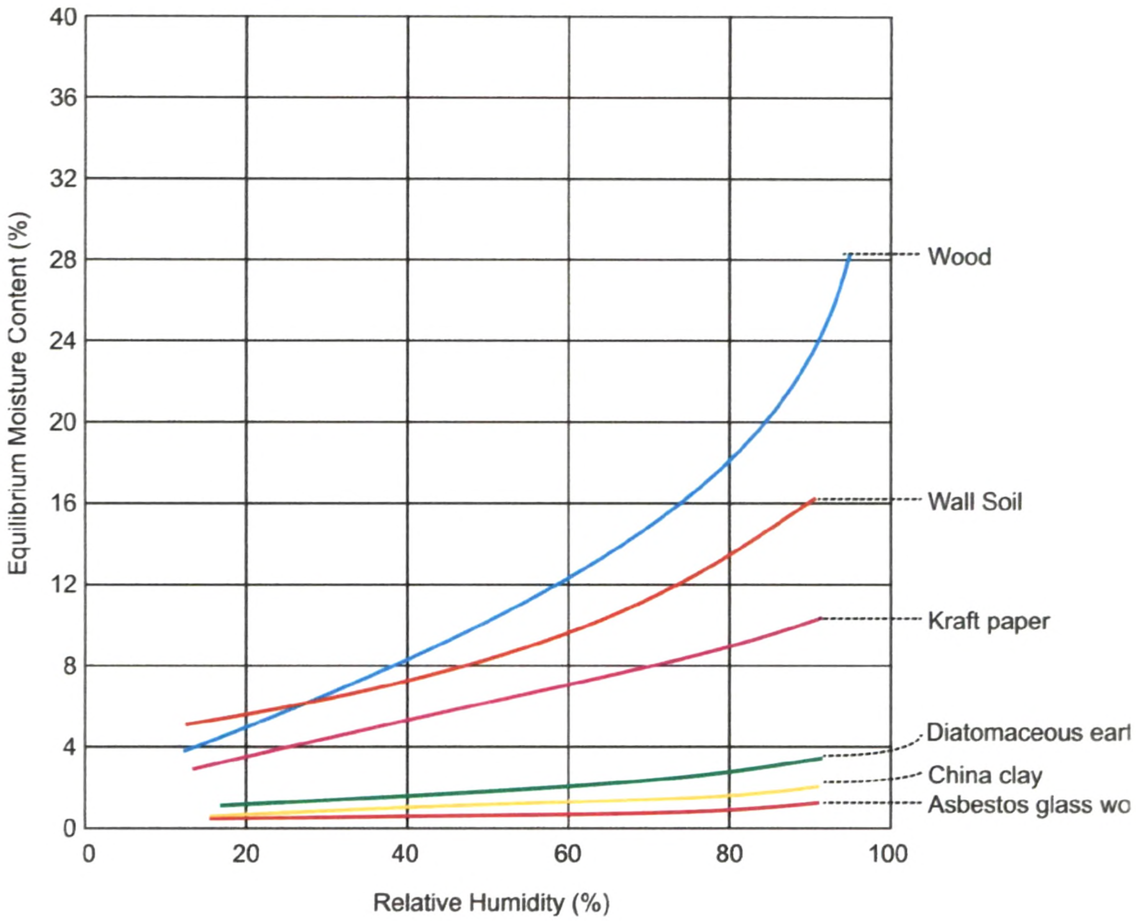

Figure 1: Moisture Content of some construction materials (Kenjo (2005)

Some organic coatings intended for use on wood, particularly oil paints pigmented with zinc and titanium oxides, swell markedly when immersed in water. When water (from either the exterior or the interior of a building) collects at the back of such a paint film, it expands in area more than the corresponding substrate and is forced off the surface, with resultant blisters. Water can also cause blistering of coatings that swell only slightly if more moisture collects at the interface than can be transmitted through the film. When the hydrostatic pressure exceeds the adhesive strength of the film, blistering occurs. Swelling properties, permeability and adhesion to moist surfaces have, therefore, been considered important parameters in the assessment of exterior coatings for wood. Moisture can cause degradation of coatings on metal if it can permeate the film and initiate corrosion, the products of which can disrupt the coating.

Roofing materials, which are used for their waterproofing ability, and plastics are generally little affected by water. Glass-reinforced plastics can be damaged if the fibres are too close to the surface or the resin weathers away, allowing water to wick along the fibres and reduce the reinforcing action. Frozen water in the form of hail can damage brittle plastics by impact. Sealants in the bulk are unaffected by water, but their adhesion can be destroyed if water attains access to the interface. Such failures occur most often on porous substrates that can absorb water.

iii. Temperature: Temperature can have both a physical and a chemical effect. Physically, a change in temperature alters such attributes as hardness and strength, which are related to the tensile properties of the material. A temperature increase softens materials that do not contain much cross-linking between the molecules, i.e., the thermoplastics. Those that are highly cross-linked usually decompose before much softening occurs; these are the thermo set materials.

Decrease in temperature increases the hardness or modulus of organic building materials and if they become too hard they may not perform their function properly. In addition, a sudden change in temperature in either direction can cause internal stresses in thick sections owing to the low rate of heat transmission of most organic materials. With such a change, the outer surface responds quickly to the new conditions while the inner portion is still at the original temperature. Thermal shock can thus lead to surface cracking if the exterior contracts rapidly while the interior is expanded, or to interior cracking under the reverse conditions. Chemically, temperature changes the rate of reactions. Oxidation, which is a slow reaction at room temperature with most materials, takes place much more quickly at elevated temperatures.

After coatings have been cured, low temperatures do not affect them particularly unless they are subjected to impact. Neither does higher temperatures experienced in weathering have any direct effect. Because coatings are applied in thin films, thermal shock is not generally important.

Sealants that have been properly formulated resist the forces exerted by high temperatures (softening of the material and thermal expansion of the jointed units), which tend to make them flow. Low temperatures, such as those experienced in many parts of Canada, place extreme demands upon sealants because they must elongate most when they are least able, owing to hardening or stiffening. Rate of temperature change is also important because organic materials, in general, can accommodate slow rates of strain much more readily than fast rates of strain.

Plastics designed for use in buildings are not softened in hot weather, although the ability of thermoplastics to support a load may be reduced owing to creep. Low temperatures make them stiffer but most do not become brittle. Rigid (unplasticized) polyvinyl chloride, which is only used where extreme chemical resistance is required, and polymethyl methacrylate, which has good clarity, already have little impact resistance because they are in the glassy state at normal temperatures. Thermal shock, especially when cyclical, can cause cracking or exudation of plasticizer from plastics.

Temperature extremes also place demands upon asphaltic and tar roofing materials. If a hard material is used so that it will not flow in the summer sun, it may become brittle and crack badly at low temperatures, and vice versa. Thus the selection of the proper grade requires considerable care. Because of the need to resist flow at high temperatures, the material can only withstand low temperature shrinkage that is uniformly distributed, emphasizing the importance of design. Moderate flow at high roof temperatures is designed to overcome small cracks caused by low temperatures.

iv. Gases: The atmospheric gas most damaging to organic materials because of its high concentration and reactivity is oxygen. Chemical linkages that are not completely "saturated" or satisfied (chemically called double bonds) are particularly susceptible to oxidation. Indeed, this is the basis of the drying mechanism of oil paints and other coatings that cure through oxidative polymerization. Because it is impossible to have a binder that contains the exact number of double bonds to cause solidification but no more, the reaction continues past the optimum stage and becomes part of the degradation process. Hence, oil paints, which depend solely upon this drying process, are more susceptible to continued oxidation than coatings, which include other methods of polymerization, e.g., alkyds.

Natural and many synthetic rubbers contain unsaturation and consequently oxidize, leading to discoloration, hardening, crazing and finally cracking. Unsaturation, however, is not essential for oxidation; polymers that contain reactive hydrogen atoms are also attacked: polystyrene and polyethylene, for example. Because oxygen must diffuse into the material to continue the reaction, oxidation often occurs only at the surface unless the material is in a thin film.

The other major gases, carbon dioxide and nitrogen, do not react with organic building materials and are frequently used in chemical synthesis as inert atmospheres. Rapid movement of the normal atmosphere, wind, can cause weathering by impinging rain, sand or dust upon exposed surfaces. Degradation of coatings is usually more severe on the sides of buildings that bear the brunt of storms.

Ozone is normally present only in the upper atmosphere and can be considered a pollutant at ground level. Being an unstable modification of oxygen, containing three instead of the normal two atoms, it is extremely reactive. Materials that oxidize will therefore react with ozone. An illustration of this is ozone-cracking of rubbers. Sulphur dioxide, present in industrial atmospheres from the burning of sulphur-containing fuels, is the other common pollutant. Its action is to form sulphuric acid, which may diffuse through organic coatings and attack the underlying metal.

b. EARTHQUAKES

Earthquakes are, perhaps, the most unpredictable environmental hazard. Perhaps the biggest irony of the moment is that earthquakes do not kill people but buildings do. A survey carried out of the *Chamoli* earthquake found that the structure with cross ties performed satisfactorily. In the earthquake prone *Uttaranchal* hills, folk wisdom places great emphasis on quality of construction. Apart from the proper selection of sites, the foundation was laid using the interlocking technique (*Jor-tor*) in which stones were wielded with one flat stone and the space between was filled with fine rock pieces. Similar attention was paid to the corners. No wonder many temples have managed to survive the quakes that shake the area routinely. The survey of the different parts of greater Himalaya indicated that the inhabitants constructed their houses with the designed anti seismic arrangement. They might be the sufferer of earthquake in the past; hence they applied indigenous technique of house construction. The building weight was distributed into different components with horizontal and vertical wooden beams embedded into the stone-masonry wall. Such type of structures can be seen in the entire hill region of *Uttaranchal.* Due to this design some of the triple storied traditional buildings successfully survived several seismic shocks in the last century.

c. COMBINATIONS

Two elements of weather, acting together, almost invariably produce greater deterioration than either one alone. There are many examples of this synergistic action. When UV breaks a polymer chain, water can remove low molecular weight materials that could act as plasticizers, thus adding to the brittleness caused by cross-linking. Leaching by water of irradiated lignin is responsible for the graying of exposed wood. Materials that have been irradiated oxidize much faster than those that have not, and photo-oxidation is one of the chief reactions in degradation. Most polymers are much more stable to heat in the absence of oxygen than they are in its presence; and more stable to oxygen in the absence of heat. For example, toughened polystyrene can be heated at 260°C for 20 hours without change, but in air either heat or UV cause yellowing and embrittlement at lower temperatures. Plastics softened by heat are more readily eroded by wind-driven sand. Both oxygen and water are involved in the rusting of iron, which disrupts organic coatings. Ozone cracking occurs sooner when the material is under mechanical stress. If three elements act together, the result is even more complicated.

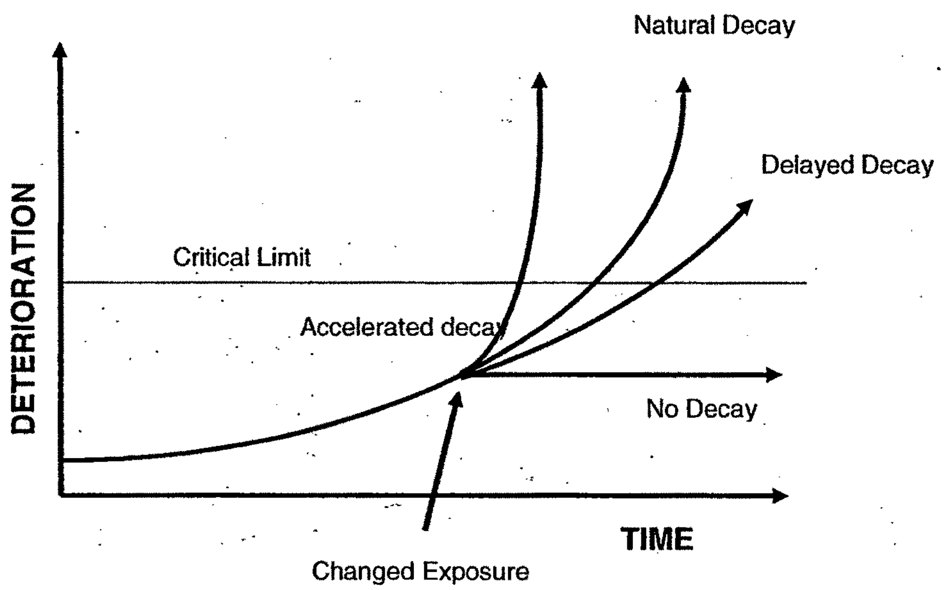

Figure 2: Service life, depending on change of exposure

(Mattson and Oftedal, 2005)

Norwegian studies by Mattson and Oftedal in 2005 indicate quite clearly that the decay of wood due to natural exposure is more or less predictable. One explanation is the traditionally use of pine logs with an extensive amount of heartwood, which ensure a clear limitation regarding to growth of wood-decaying fungi and wood-boring insects. Another reason for long service life of wood is the "favourable" climate (a combination of generally low precipitation and low temperature) and constructions based on long-term experience. Inserting protection layers, such as cladding outside the log construction has a traditional development through the 18th and 19th century. At the same time, expanding use of surface treatment by tar products, oil paint, linseed-oil paint and stains gave further protection from humidity and prolonged the service life. "Unpredicted" or extensive decay is often due to relatively clear events/change in exposure (figure 2).

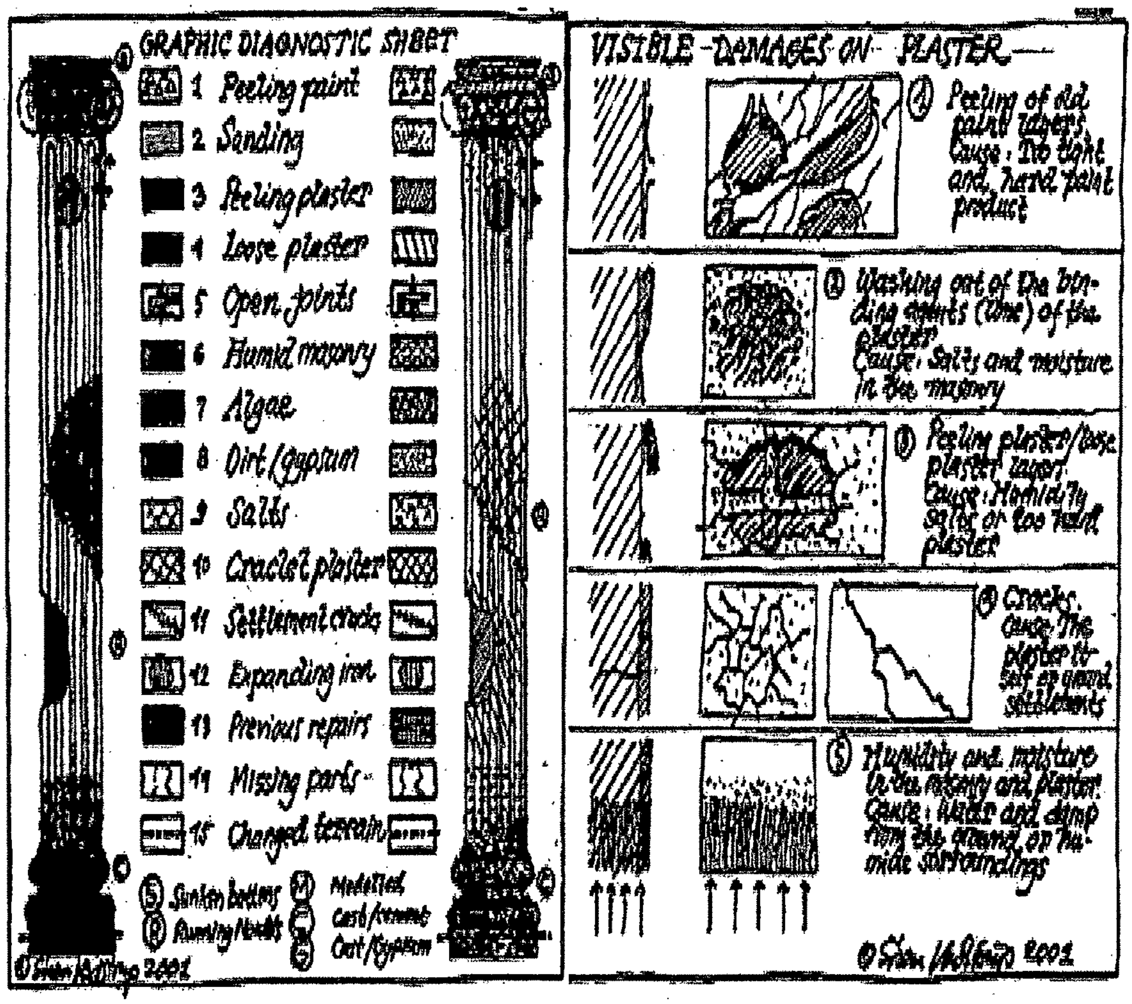

Plate 2: Graphic diagnose sheet of visible deterioration and damages

(Vadstrup, 2005)

Therefore, the above factors collated following five causes for most of the deterioration and damages (Plate-1) in the organic building materials:

6 **Influence of water:** and the consequences or followers of water: Moisture, ice, saltwater, acid rain. This causes dry rot and fungus in wood, salts in masonry and stones, frost damages, acid deterioration, algae, dirt etc.

7 **Mechanical causes:** from wear, ground decreases, insufficient carrying capacity and wind.

8 **Technical faults:** from insufficient constructions: Leakages, insufficient adjoints between materials, too hard and moisture tight surface treatments or finishing coats, changes in the physical balance in the constructions.

9 **Forced deterioration** of the surface materials due to leakages in the roof, joints, watertight surface on iron etc.

10 **Other causes:** incorrect use and arrangements, neglect of maintenance.

The literature cited above made it evident that the well-known elements of weather; radiation, moisture, thermal conditions, gases and earth quakes, etc. affect life and performance of building materials further affecting indoor environment. Changed use (no more heating, lack of maintenance) or construction of the buildings (new materials, thermal insulation) may be the factors that provoke an accelerated rate of decay. Even small changes, such as applying a modern paint system, can be sufficient for a major change in rate of decay.

2.3 Review of Studies Conducted In India and Abroad

Organic materials used on or in buildings can be classified according to their use (Ashton, 1969) which further makes a housing environment. Environment living conditions, including housing conditions, are among the primary determinants of an individual's health, thus its performance and have attracted the interest of public health scientist since ancient times (Foster, 1992; Ineichen, 1993 and Krieger, 2002). Some of the studies for the interest of the present research have been summarized as under:

a. Review of Studies on Organic Building Materials

Gudkin *et al.* (1971) have felt that four main classes of natural polymeric compounds are poly saccharides, proteins, fats and lipids and the information encoded polydeoxyribose nucleic acid and polyribonucleic acid (DNA and RNA). The properties of these compounds are important for understanding cellular functions and for the utilization of the cells for bioconversions.

It was found by **Kirk (1975)** that polystyrene can be changed to biodegradable monomers introducing some functional groups which are characteristic of lignin into benzene ring.

Review of **Carlisle (1976)** includes utilization for electric power generation, home heating and insulation, chemical extractives etc. the 'Energy Forest' concept is analyzed; it involves the management of an entire forest area for continuous harvesting and subsequent conversion to energy. It is concluded that utilization for utilization for fuelling large power plants is not economically attractive at present, but that there is potential for small scale power production and for the use of mill residues to provide mill energy. The conversion of forest biomass to liquid and gaseous fuels is technically possible but costs are high. The potential is discussed for the utilization of forest products for medicinal and chemical extractives and for fodder. It is suggested that energy could be conserved by the use of wood in house construction instead of metals and plastics needing large amounts of energy to manufacture. Methods to increase yields for such uses are discussed and their social and environmental implications are considered.

Dinwoodie (1977), in his study found out that the loss in strength and stiffness occurred in unstressed UF chipboard cycled between 30 percent and 90 percent RH at 25 ^{0}C may be due to chemical or mechanical degradation of the adhesive. The results of strength tests on thin, cast films of UF adhesives, having a range of formaldehyde to urea ratios, exposed to cyclic humidity changes at 20 ^{0}C, indicate that the loss in strength and stiffness is unlikely to be due to chemical changes in the adhesive. Similar results were obtained with adhesive films stored in the presence of sawdust. The method of preparing thin, clear, cast films of uniform thickness is described.

Stryer (1981) studied that wood has been in use as a construction material while several gadgets made from natural organic materials like leather gaskets, felt packing, fiber bending and oil lubricants are being used. Efforts are continuously being made to improve the engineering properties of organic materials. Development of plywood has overcome the non uniformity in wood and still better physical properties are obtained when the pores of wood are impregnated with a thermosetting resin. The ingenuity of technologies in working with organic materials improved the engineering properties of natural as well as synthetic polymers. Great strides have been made and continue to be made in the utilization of such materials.

Webb (1985) presented a discussion on how appropriate building technology can have a significant impact on the transmission of vector borne disease is presented. The earth used in traditional rural housing can be stabilized against erosion, shrinkage and cracking by the addition of bitumen, cement or lime. Stabilized earth can be further improved by compaction in a mechanical press, such as the CINVA ram or the BREPAK machine, or by ramming it firmly with wooden mallets between heavy formers. The use of compressed soil blocks could result in the creation of fewer niches for vector and nuisance arthropods in the domestic environment, as well as better retention of insecticides on their relatively non porous surfaces.

Bailey *et. al.* (1986) investigated that biopolymers are polymers produced by living organisms and are either repetitive or non-repetitive in structure. Repetitive biopolymers like starch and cellulose contain one kind of monomeric unit. Non-repetitive polymers like proteins may contain from several up to 20 different monomer species.

According to **Merritt (1986)** organic materials are perhaps the oldest construction materials. Through many generations of use, people have found ways of getting around some of the limitations of naturally occurring organic construction materials. Plywood for instance has overcome the problem of the highly directional properties of wood. In addition to improving natural materials technologies have developed many synthetic polymers (plastics), which are important in current construction.

Naas (1986) examined the effect of climatic conditions on deterioration of agricultural construction materials for a variety of climates. Concrete was susceptible to excessive deflection of structural members, cracking and corrosion of reinforcement particularly at high temperatures and high relative humidity. Concrete-masonry structures in tropical countries also suffered from thermal stress. Relative corrodibility of steel was compared for 20 dry, tropical, inland, marine, rural and industrial locations throughout the world, with high relative humidity in tropical climates causing corrosion in junctions and welding bands. Wood was particularly susceptible to fungus attack.

A standard procedure was devised by **Zigel and Obsedshevskii (1988)** for evaluating the changes in the glossiness, colour, dirtiness, chalking, local bulging, cracking, delamination and break-up of lacquer coverings of fibre boards. All these features are combined by formulae into a single evaluation expressing the resistance of the decorative and protective properties. Data are presented showing the change in the resistance of 5 different lacquer coverings on fibre boards exposed to the air on the roof of a building from 1985 to 1987. The best coverings are identified, and the durations of satisfactory performance are determined.

On the basis of studies in Switzerland, the ecological aspects of the use of timber preservatives were discussed by **Graf (1989)** with regard to the risk of attack by the house longhorn (Hylotrupes bajulus) and the possible dangers from the preservatives. A decision making diagram is constructed for preservative measures against H. bajulus, aqueous products and organic products.

Lapko et. al. (1989) examined degradative processes occurring in wooden ceilings and roofs of a 300 year old building and the changes in strength of the wood resulting from cracking, dry rot and other micro organisms, wood worm, etc. discussed.

An analysis was made by **Davenne et. al. (1996),** of the failure of joints with dowel type fasteners in glued laminated timber under static loading. The single bolt loaded the wood parallel to the grain. The joint failure was due to cracking along the grain direction. An experimental programme was carried out to investigate joints with different structural parameters and with different bolt diameters. Fracture was analyzed by linear elastic fracture mechanics concepts. Possible pure or mixed modes of fracture were investigated. The crack propagation was assumed to be based on a comparison of the energy release rate with a critical value. An analysis of elastic stresses was carried out for the prediction of the onset of cracking. The critical energy release rate value was obtained from experimental results of fracture tests under three point bending. The comparison between experimental and numerical results for the simulation of fracture in joints showed that the linear elastic fracture mechanics provides a good approximation of load bearing capacity of bolted joints and may help improve design codes.

Raghavan, V. (1998) classified building materials in three broad groups according to their nature:Metals and alloys, Ceramics and glasses, Organic polymers. He also stated that organic polymers are relatively inert and light and generally have a high degree of plasticity. Figure 3 lists typical examples from each of these three groups of materials.

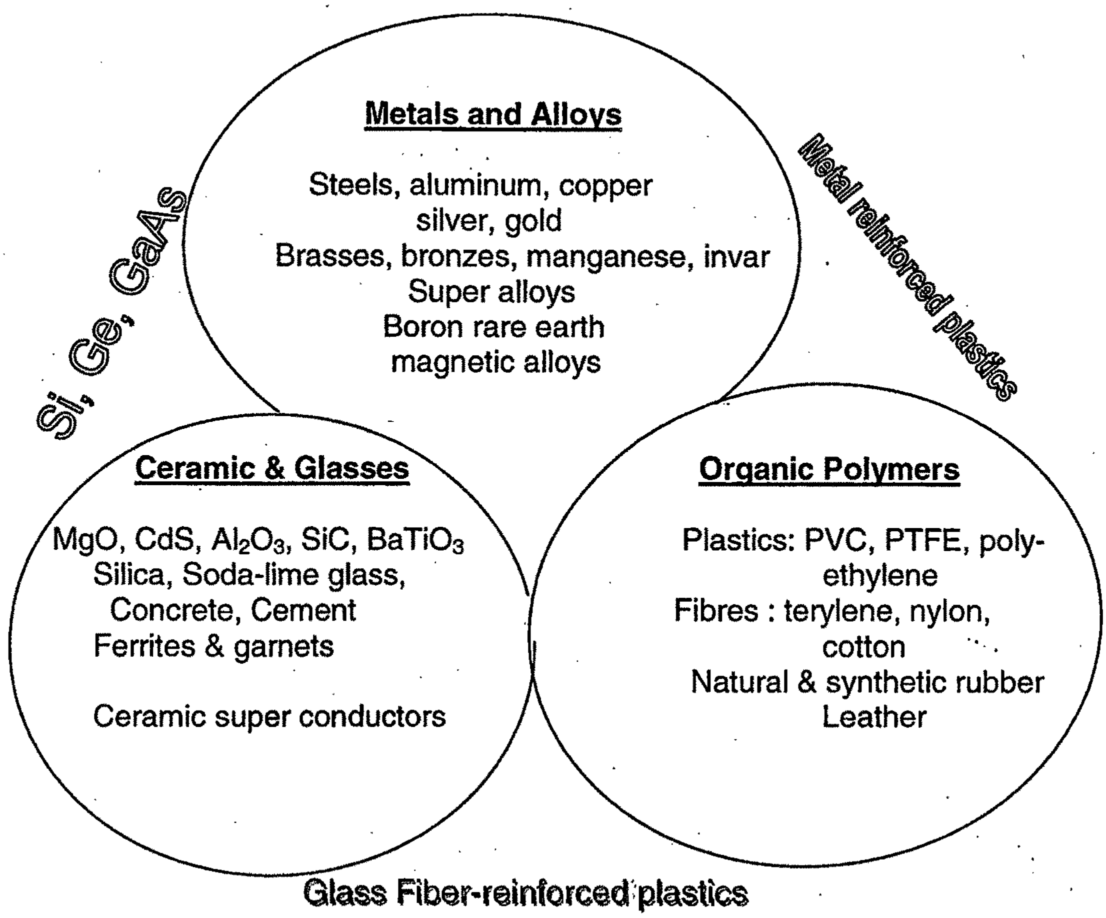

Figure 3: Classification of Engineering Materials (Raghavan, 1998)

Challa (1993) has expressed that during the last few decades, polymeric materials have been the fastest growing chemical industry. In the construction industry, we find numerous applications of polymers in piping, resilient flooring, electrical insulation, paints and decorative laminates. The use of polymers now outstrips that of metals on a mass basis.

Ak et. al. (1994) studied decontamination of plastic and wooden cutting boards with a view to preventing cross contamination of foods in home kitchens. New and used plastic (four polymers plus hard rubber) and wood (nine hardwoods) boards were cut into 5 cm square blocks (25 sq. cm. area) for these experiments. Bacterial contaminants – Escherichia coli (two nonpathogenic strs plus serotype 0157:H7), Listeria innocua, L. monocytogenes, or Salmonella typhimurium-applied to the block surface in nutrient broth or chicken juice, were recovered by soaking the surface in nutrient broth or pressing the block onto nutrient agar, within minutes or 12 hour later. Persistence and overnight multiplication of bacteria on plastic surfaces depended on maintenance of humidity so as to prevent drying of the contaminant. New plastic cutting surfaces were relatively easy to clean and were microbiologically neutral, but plastic boards with extensive knife scars were difficult to clean manually, especially if they had deposits of chicken fat on them. Fewer bacteria were generally recovered from wooden blocks than from plastic blocks. Clean wood blocks rapidly absorbed all of the inoculum, after which the bacteria could not be recovered within 3 to 10 min. If the board surface was coated with chicken fat, some bacteria might be recovered even after 12 hour at room temperature and high humidity. Cleaning with hot water and detergent generally removed these bacteria, regardless of bacterial species, wood species, and whether the wood was new or used.

In another research paper, **Ak et. al. (1994),** reported the microbiology of plastic and wooden cutting boards, investigating cross contamination of foods in home kitchens. New and used plastic (four polymers plus hard rubber) and wood (nine hardwoods) cutting boards were cut into 5 cm squares ("blocks"). Escherichia coli (two nonpathogenic strs plus type 0157:H7), Listeria innocua, L. monocytogenes, or Salmonella typhimurium were applied to the 25 cm^2 block surface in nutrient broth or chicken juice and recovered by soaking the surface in nutrient broth or pressing the block onto nutrient agar, within 3-10 min or upto 12 hour later. Bacteria inoculated onto plastic blocks were readily recovered for minutes to hours and multiplied if held overnight. Recoveries from wooden blocks were generally less than those from plastic blocks, regardless of new or used status; difference increased with holding time. Clean wood blocks usually absorbed the inoculum completely within 3-10 min. If these fiuids contained 103-104 c.f.u. of bacteria likely to come from raw meat or poultry, the bacteria might be recovered from wood after 12 hour at room temperature and high humidity, but numbers were reduced by at least 98% and often more than 99.9%. Mineral oil treatment of the wood surface had little effect on the microbiological findings. These results do not support the assertion that plastic cutting boards are more sanitary than wood.

Foster *et. ai.* (1994) listed that petrochemical industries produce many types of high polymers among which polyethylene, polypropylene, polystyrene and PVC are most widely made and used. These and other synthetic polymers are very useful as packaging and construction materials because of their physical and chemical properties. However, the disposal of these polymers has become a serious public health problem because they are not easily degraded in nature. Biodegradation of water soluble polymers is thought to be easier than that of insoluble ones. Polyethylene glycol and PV alcohol for example, are known to be attacked easily by microorganisms. Oligomers of water insoluble polymers such as polyethylene, polyurethane, aliphatic polyester and nylon-6 are also known to be degraded only with difficulty by microorganisms. However, polystyrene, which is an aromatic polymer, is resistant to microorganisms and other biodeterogenes.

Motohashi (1996) evaluated twenty three kinds of pigment stain coating specifications through the outdoor exposure test. An old type of oil stain made of boiled oil and stain agents, alkyd paint and acrylic emulsion paint were also exposed for comparison. The data obtained show that durability performance levels among the commercial products were remarkably and widely scattered, which is considered to be partly due to lack of material standards. There are many brands of pigment stains on the Japanese market nowadays; however, no material standard is available for distinguishing commercial stains. As to the old type of oil stain, it showed the fastest deterioration among all the specimens. As a result, it can be said that the durability levels of the commercial pigment stains are distinguishable from that of the old type of oil stain although they vary widely. The alkyd paint and the emulsion paint showed little apparent deterioration except for slight chalking within 16 months. On the other hand, some of the pigment stains showed visible deterioration patterns; that is, those specimens showed gradual and fine cracking, peeling and flaking. Such a deterioration pattern is generally considered to be more favourable for repainting than alkyd paints and acrylic emulsion paints which form thicker coated layers and deteriorate unequally.

Oliveira (1997) reported field test results of new tools for triatomine control developed under the sponsorship of WHO/TDR: (1) a slow release formulation of insecticidal paint, containing malathion, applied by spraying; (2) fumigant cans which, when lit, release smokes containing cypermethrin and DDVP (dichlorvos); and (3) sensor boxes for the detection of triatomine infestations. Field assays were performed in Chile, Honduras and Paraguay against Triatoma infestans, T. dimidiate and Rhodnius proxlixus, according to a standard protocol designed by a WHO expert committee. Preliminary 6 months post treatment results for the 3 countries showed efficient vector control when insecticidal paints were used indoors and in the peridomestic environment, keeping reinfestation near to zero. The final results presented for Chile at 2 years post-treatment confirmed the superiority of the slow release insecticidal paints. Sensor boxes were less effective than man hour captures for the detection of infected houses.

Turkulin et. al. (1997) analysed weathering of wood and concluded that wood in exterior structures undergoes certain chemical and physical changes which cause the slow degradation of wood surface (weathering). The disintegration is caused by the combined action of ultra violet light from the sun, moisture and oxygen from the air and additional effects of wind, rain and other precipitation. Wood changes colour, roughens and erodes with time. Possible biological attack excluded, weathering is the most serious risk to wood for building purposes. Encouraging the use of wood as the main material for the joinery and other building components depends mainly on the exploitation of the results of research on the improvement of the wood durability, its modifications and its correct and efficient finishing in order to reduce the maintenance costs and extend the service life of protective and decorative coatings.

Cecere et. al. (1998) reported the environmental and demographic risk factors associated with the domestic infestation and density of T. infestans in 3 heavily infested rural villagers in Santiago del Estero Province, Argentina, in 1992-94. In a one factor unadjusted analysis, the number of T. infestans captured per person hour was associated significantly and negatively with the use of domestic insecticides by householders, type of thatch used in the roofs and the age of the house and positively with the following: degree of cracking of the indoor walls and presence of hens nesting indoors. In one model, using multiple linear regression and a backward stepwise elimination procedure, most of the variation in the overall abundance of T. infestans was explained by insecticide use and the presence of hens nesting indoors; in another model using the same procedure it was explained by insecticide use, bug density in 1988 and previous spraying with deltamethrin in 1985. Variations in bug density per capture stratum (household goods, beds, walls and roof) were explained by the bug density in other strata and by 1 or 2 of the following risk factors: hens nesting indoors, type of roof, presence of cracks in the walls and number of people living in the house. Bug density might be locally controlled by the availability of refuges in the roofs and walls, by the presence of hens nesting indoors and by the use of domestic insecticides. Certain local materials, such as a grass known as symbol, could be successfully used in rural housing improvement programmes aimed at reducing the availability of refuges for insects in the roof.

According to **Heinrich et. al. (1998)** genetic predisposition and indoor exposure to allergens especially during the very early childhood years are major factors for the development of allergic diseases later in life. The present study analysed the association between allergic sensitization in 811 children aged 5-14 years old and residing since birth in homes made of different construction materials. Indoor factors were investigated using a questionnaire and allergic sensitization was assessed by a skin prick test. The prevalence of allergic sensitization was compared between children who lived since birth in 5 different types of building. After adjustment for age, gender, parental education and study area the odds of allergic sensitization were higher among children who lived in prefabricated concrete slab buildings built after 1970 (OR=1.56%, 95% CI=1.02-2.38) and among children who lived in new brick buildings (OR=1.75, 95% CI: 0.88-3.47), than among children who lived in old brick buildings. Moreover, the odds of pollen sensitization was higher among children who lived in the new buildings (prefabricated slab buildings: OR 1.68, 95% CI: 1.04-2.72); new brick buildings: OR 1.48, 95% CI: 0.64-3.42) while living in timber framed houses associated with higher odds of sensitization against Dermatophagoides farinae and D. pteronyssinus (OR 1.63, 95% CI: 0.77-3.44). The step by step inclusion of single indoor factors like type of heating, numbers of storeys, number of people per room, environmental tobacco smoke, use of gas for cooking purposes, dampness of the home or visible moulds in the logistic regression model only marginally changed the odds ratios. Modern living conditions are associated with higher odds of allergic sensitization.

Johanning et. al. (1998) tested samples of building materials (drywall, fiberglass, wallpaper, wood) from various homes or wok places in the USA, which were visibly contaminated with moisture-related fungi, with indirect (feline fetus lung cell assay test) and direct (tetrazolium MTT cleavage test) cytotoxicity screening tests that are particularly sensitive to S. chartarum toxins. In addition, microscopic, chemical, immunochemical (roridin A enzyme immunoassay) and mycological culture analyses were performed. In all cases in which building occupants had reported verifiable skin, mucous membrane, respiratory, central nervous system or neuropsychological abnormalities, cytotoxicity was identified. It is concluded that results of cytotoxicity screening test of field samples, such as the direct MTT test method, will give investigators of health problems related to indoor air quality important toxicity information.

Monroy et. al. (1998) in their study showed the effectiveness of house modification for the control of Chagas' disease vectors under natural and artificial conditions. Wall plastering and paint were evaluated for the control of populations of triatomines by assessing vector numbers in man hour collections before and after modifications in 1993. The authors evaluated 29 houses from 3 small villages in Villa Canales in the Department of Guatemala; 18 of them had some kind of modification or improvement. In houses covered with plastered cement and lime, the authors found a 92% reduction of the total vector population in the following year. Others houses with partial modification and paint with lime showed a reduction of 53% and 35%, respectively. In houses without improvements, the number of vectors remained the same. Triatoma dimidiate and T. nitida were collected in the houses; the infection rates with Trypanosoma cruzi were 21% and 50%, respectively. After the house modifications there were no significant changes in the infection rates. There was no statistical difference in longevity of T. dimidiate when kept under artificial conditions (simulated wall plaster) compared to that observed in the field.

Razek (1998) presented in his paper about a thermal investigation of traditional house tested experimentally under the effect of external climatic conditions of hot dry region in Egypt (Toshky region). The external and internal walls of the test house were constructed from local sandstones blocks with 50 cm thick. The ratio between the external openings and the external walls surfaces areas is less than 20%. The external wall is covered internally with 2-3 cm cement mortar plaster, while the internal walls covered with 2-3 cm cement plaster from both sides. Volts and domes covered the roof of the test house. The external surface of the roof covered with 2-3 cm white cement mortar plaster. The results of the investigation demonstrated that, the local building materials such as sandstone suppress the swing of external outdoor air temperature and stabilize the indoor air temperature at average level below the average of outdoor air temperature by about 2-3^{0}C only during the hottest period. The results also show that modern insulating materials, together with the local building materials make it possible to maintain the indoor air temperature significantly below the average of the out door air temperature by about 4-5^{0}C and passive cooling systems makes it possible to maintain the indoor air temperature to the thermal human comfort zone or near it. The results showed that evaporate cooling is essentially during the hottest critical period in Toshky region as a passive system.

Sastry and Radhakrishna (1998) indicated quite clearly that industrial use of rubber includes tyres, tubes protective linings in tanks, pumps, rubber beltings etc. Hand rubber is used in electrical insulating parts, chemically resistant pipes and equipments etc. Foam rubber made by incorporating gas into latex followed by vulcanization is used to make pillows, mattresses, furniture cushions etc. Sponge rubber is produced from rubber by blowing sodium carbonate and injecting fatty acids. Sponge rubber is used sealing, heat insulating, cushioning and shock absorptions. Glues obtained from animal gelatins, vegetables and starches are widely used adhesives. Adhesives made from polymers include cellulose acetate, cellulose acetate butyrates and polysoxylin. These are thermosetting and thermoplastic adhesives Xanthan gum is commercially the most widely produced gum using Xanthamones compacting. Animal hides contain collogues which can be hydrolyzed into glue or gelatin.

Despot et. al. (1999) investigated that the L – joints which were made of home grown Croatian silver fir (Abies alba) sapwood and prepared according to EN 330, were used to establish the influence of coating type and colour on the durability of exterior fir wood joinery. The L- joint's surfaces were treated with two types of coatings and exposed for 36 months in Zagreb. The first type of coat was alkyd paint and the second was stain, both in three different colours; white, brown and black. The L-joints described in this article were not treated with chemical preservatives and were examined after 1, 2, 3, 4, 6, 12 and 36 months of exposure. The influence of coating type was decisive on the moisture contents and permeability during exposure. Regardless of the period of exposure the L-joints coated with stain always had lower average moisture contents and a lower increase in permeability than those coated with the alkyd paint. It happened due to the well known stain vapour diffusively. The influence of the coating type, but it was evident during almost all the exposures. Darker surfaces, particularly during sunny periods absorbed much more heat rays which caused accelerated seasoning, lower moisture content and a smaller increase in permeability.

Trajkovic et. al. (1999) in their study reported that chemically untreated pine (Pinus sylvestries) and fir (Abies alba) wood L-joints coated with reference white alkyd paint were exposed outdoors for one year according to EN 330 at two different climatic sites: Garston (UK) and Zagreb (Croatia). Pine wood is the standard reference species for testing the exterior joinery and fir wood is the most frequently used species in the Croatian joinery industry. The aim of the work was to establish the difference between these two species considering the moisture content (MC), permeability and bacterial and fungal infection and colonization during exposure. In this article only moisture content, as the main factor of microbial activity and permeability, is presented. The fir wood L – joints mostly had lower MC than the pine L- joints at the same position and site during exposure. In regard to the exposure sites, the differences were larger in Garston than in Zagreb, particularly at the end of exposure. This fact is ascribed to lower natural permeability of fir wood than pine wood, which was emphasized by the specific climatic characteristic of exposure sites. The results indicate that fir sapwood L- joints could also be used in further investigations of home made joinery, wood preservatives and coatings.

The paper by **Yang et. al. (2001)** discusses the research conducted on the use of plastic composite in home and abroad and prospect and development trends in wood plastic composite production. Wood plastic composite which is an ideal substitute for wood has more perfect properties than both wood and plastic only. The compounding of wood and plastic separated from solid waste as well as the use of the law of modern composite materials development decreased potential pollution problem in the cities which are caused by waste wood and plastic.

Turkulin and Sell (2002); Wood in exterior conditions undergoes a series of chemical and physical changes that impair its aesthetic appeal and durability. The cladding of the high aesthetic, thermal, other physical and technical demands over a long period of decades, sometimes centuries in use. In order to keep the functional properties of wood unchanged in a long service life, a variety of protective measures may be employed. Physical protection is marked as the most important way to keep the harmful effects of ultraviolet light and precipitation away. Design details of wood products in facades, as well as their assembly means, are considered from the view point of their durability. Chemical protection should generally be avoided, i.e. restricted to a small number of cases when it simply can not be avoided, but surface finishing plays a major aesthetic and technical role in designing and maintaining the wooden facades.

Several efforts by the researchers and engineers have been made to classify engineering materials on the basis of basic structure, origin, use, properties, mechanism, electrical conductivity, etc. It has been investigated that chemical and physical changes impair aesthetic appeal and durability of the building materials and a variety of protective measures could be of great help in keeping them functional. Energy conservation could be practiced by using alternative building materials for naturally occurring building materials.

b. Housing and Human Performance

Azer, *et al.* (1972) provides more evidence that hot conditions have significant affects on performance only when they cause a rise in body temperature. In their experiment, performance decrements occurred when subjects worked at 35^0 C and 75 per cent relative humidity, but not at 35^0 or 37.5^0 and 50 per cent relative humidity. Relative humidity seems to be a key determinant of performance in a variety of tasks.

Results of research conducted by **Buell et.al. (1973)** revealed that skin tests of 546 people in one area revealed 165 (30.2%) reactors but no point source of infection was found after a diagnosed case led to rumours that a focus of infection started the outbreak. In the 2nd community Histoplasma capsulatum was isolated from 10 to 44 soil samples from a wood frequently by starlings. Skin tests conducted on 3750 school children revealed 633 (16.9%) reactors. A higher prevalence of histoplasmin reactors resided near the contaminated woods. Both investigations showed that increased prevalence was associated with males, increased age, farm residence, years lived at residence and play areas in woods, birds roosts or old buildings.

An infestation of Ornithonyssus bacoti (Hirst) in a farm house in a scattered village near Dresden that was investigated by **Eichler et. al. (1973)** is described because they believe it to be typical of many occurring in Eastern Germany. The farm house was of wood, and the yard was surrounded by buildings. The general appearance was very clean, though rats (Rattus rattus) were present. R. rattus is increasing in numbers in Eastern Germnany, occupying niches vacated by R. norvegicus, which is being intensively controlled. The mites were a serious pest of man every winter, causing severe inflammation of the skin by their bites, particularly in small children who were attacked while asleep. The mites were particularly abundant in the living room. Attempts at control with preparations containing DDT, gamma BHC (lindane) and pyrethrum were unsuccessful.

Christensen (1975) had given a popular account of the harmful effects of fungi in relation to man and animals such as, airborne fungus spores, plant disease and respiratory allergy; fungus predators and parasites of nematodes and insects; fungi pathogenic in man and animals; decay of wood in trees and buildings and fungi.

Annual Report (1977) from Denmark on vertebrate and invertebrate pests of man, domestic animals, building and stored products (including timber) includes sections on advisory work, in which the incidence of enquiries relating to many pests in 1977 as analysed, wood boring pests and their control and on mites, including those in stored grain.

According to **St. Leger and Yarnell (1977) and Smith (1989)** stress and depressive illness are likely to be linked with current housing conditions, as are frequent episodes of acute respiratory illnesses. A long term implications for health may be experienced many years later, perhaps at a time when current housing conditions are good. There is a growing evidence of an association between frequent or severe bouts of respiratory illness in childhood and lung function in later life.

Allen and Fischer (1978) found that if relative humidity was held constant at 40 per cent, performance on a simple learning task did not vary over range of 11 to 28^0 C. If relative humidity was not controlled, optimum performance was found to occur at 18^0C, 35 per cent relative humidity. Increase and decrease in temperature lead to performance decrement.

Much of the recent research by **Dunleavy (1981)** has been concerned with public sector housing, especially that which has described as 'mass housing'. It is ironic that local authority housing, a movement which had as one of its most important motivations a desire to improve working class health through better housing conditions has in recent decades produced the new slums and their associated health hazards.

Dias et. al. (1982) reported that Government strategy in Brazil for combating Chagas' disease, caused by Trypanosoma cruzi, is directed primarily towards preventing the infestation of houses by the triatomines that are vectors of the pathogen. In practice, this has mainly been resticted to insecticide spraying and transmission in several parts of the States of Sao Paulo and Minas Gerais has been successfully interrupted by this means. However, in the longer term, nearly all infestations could be eliminated in many rural areas by the diligent sealing of the cracks that provide shelter for the triatomines in the adobe walls of house or by the introduction of new building practices that abolish walls prone to cracking. The problems in persuading rural residents to replace the traditional adobe suggested that control of the disease may ultimately depend on the gradual evolution and modification of rural society through the resolution of complex and difficult social problems as well as the provision of new rural housing.

In an another study, the significance of rural housing in the epidemiology and control of Chagas' disease is discussed with reference to studies in two endemic areas, Bambui and Luz, in Minas gerais State, Brazil. Rural residents tended to resist replacement of their traditional adobe houses, which provide excellent refuges for triatomine bugs and poverty and other factors tended to limit the affected villagers' respectively to both new housing and new methods. However, community participation and other long term efforts against Chagas' disease in Bambui seem to have increased local awareness of the problem and generated home owners' interest in health related home improvements. Increased awareness among the residents of Esteios, a small community in Luz, appears to have prompted effective local control of Chagas' disease without official government intervention or support.

Pike (1981) and Strachan *et al.* (1986) defined health and ill health as, if anything, more contentious. In relation to morbidity there is the question of how this is measured-e.g. by demand for medical services, by the detection of clinical symptoms by 'experts' or by asking people themselves? There is some evidence that different methods of measurement produce rather different pictures of the association between poor health and bad housing.

Woodson (1981) has compiled the finding of many studies of the affects of noise on human performance. Although noise level below 90dB (A) is not a serious threat to hearing, they can degrade task performance and cause annoyance.

Pederson and Gravesen, (1983) contributed an interesting fact that a woman developed symptoms of headache, swollen and painful joints and breathlessness after moving into a damp house; X-rays indicated nodes in her lungs. The symptoms disappeared spontaneously when she stayed away from the house and secured on her return.

Boardman (1986) and Smith (1989) favored in case of elderly people, argued that damp, cold houses are an important factor in excess winter deaths in Britain and not just in the extreme form of hypothermia, but also in increased susceptibility to coronary and cerebral thrombosis and respiratory disease.

Byrne *et al.* (1986) indicated that dramatic improvements in housing were accompanied by improvements in health, especially as measured by mortality at younger ages or by the growth and development of children and by a decline in the incidence of those diseases most clearly associated with in sanitary and over crowded housing.

Hunt, Martin and Platt (1986) conducted a research and derived at; women in the damp houses did report significantly more emotional distress. Dampness was, however, strongly related to health problems in children. The mean number of symptoms was higher in children in damp houses, and children in damps houses were more often reported to suffer from aches and pains, diarrhea, nervousness and headaches and to have had at least one respiratory problem in the past two months. Where there was visible mould growth, there were significantly more reports of vomiting and sore throat in children.

Ineichen (1986) analyzed review on the evidence up to the mid 1980s on the effect of high-rise housing on mental health. It was concluded that 'balance of evidence' suggests a damaging effect, especially for the families with young children

Several studies by **Strachan *et. al.* (1986); McCarthy *et. al.* (1985) and Blackman *et. al.* (1989)** have found links between damp housing, the presence of mould and high rates of asthma and respiratory illness, especially among children.

Blackman *et al.* (1989) made a comparison was made in two areas of West Belfast which were both socially and economically deprived, but of which one consisted of very unpopular, high rise, poor-quality dwelling and the other of traditionally built dwellings considered to be significantly better. They found marked differences in mental health between the two areas, for men and children, as well as for women.

Carstairs and Morris (1989) car stairs in two interesting contributions first proposed the use of : 'an area base for environmental monitoring and epidemiological analysis' and 'the classification of populations by their area of residence appears to offer a superior basis for the explanation of differences in mortality between health boards than does social class.

The survey of **Glasgow District Council (1989)** indicates quite clearly that dampness has long been a concern of Scots. In Glasgow, about 70% of homes are known to suffer from dampness/condensation. People living in damp houses tend to believe that this is bad for health and that of their children.

A review of major studies listed by **Smith (1989)** shows, most attention has been paid to respiratory disease (traditionally linked with bad housing), to mental illness, particularly of the depressive type and to general stress induced morbidity. In addition, studies have considered the influence of housing and estate design on the incidence of domestic accidents. Young children, their mothers and elderly people are the groups most often argued to be affected, simply because they spend more time in the home than others.

In **Weekly Epidemiological Record (1990),** the frequency and geographical distribution of human Trypanosoma cruzi infection in the America is described, dividing the countries with endemic Chagas' disease into 4 groups according to the magnitude of transmission, quantity and quality of the available epidemiological information and existence or non existence of co-ordinated actions towards the control of this disease. The use of fumigant canisters and insecticidal paints in triatomine control is discussed briefly.

As studied by **Barros (1993)** that ventilation (air speed) is the process of air renewal. The basic purpose of ventilation should be to control the purity of the air. However, with simple ventilation, we control only the speed. For having control on the temperature and the humidity of the air, air conditioner is needed. He also reported that ventilation (air speed) is one of the basic sanitary conditions, because confined air, due to the gases from breathing and transpiration, has its composition altered by lowering the oxygen percentage and increasing that of carbonic gas and the humidity rate. Only with the constant renewal of the air conditions will be made favourable to health, through a normal breathing.

I. I. D. A. (1993) reported that when man is forced to withstand high temperatures, his efficiency drops. Work speed is reduced, the pauses become longer and more frequent, the concentration degree drops and the frequency of error tend to rise significantly, mainly when the temperature reaches 30^0C.

Bredger (1995) stated that good lighting in the home is essential for the comfort and the well being of all family members. Adequate provision of light is must to avoid wastage in time, energy and strain on the eyes.

Sorensen *et. al.* (1995) concluded that low level of lighting at home contributed to deteriorating mental and physical well being.

Pires et. al. (1999) surveyed1937 individuals of T. sordida were collected from 196 of 378 domiciliary units sprayed with deltamethrin in July 1995. Intradomicilary infestation occurred in 6% of units and peridomiciliary infestations at 99% of them. 48.3% of the peridomiciliary ecotopes studied were found to be infested, particularly those with wood as the main construction material (constituting 92.1% of the ecotopes in the survey), where 92.5% of the insects were captured, followed by those using adobe (6.2%) , where 3.8% of the insects were captured.

Rudnai et. al. (1999) measured the concentrations of formaldehyde, nitrogen dioxide, benzene, xylene and toluene were measured in the homes of school children living in 6 towns in Hungary, whose respiratory health was also assessed by a questionnaire. Passive monitors were used for air sampling. The NO_2 concentration was higher by 75 $\mu g/m^3$ in homes with a gas cooker by 80 $\mu g/m^3$ in homes with gas heaters and by 27 $\mu g/m^3$ in homes with smoking persons than in those without these pollution sources. Busy traffic nearby and gas silicate building material significantly increased the indoor concentration of formaldehyde. The concentrations of benzene and xylene in homes with floor heating or with smoking family members were also higher but due to the limited number of samples, the difference was not statistically significant. The questionnaire data on 1767 3rd grade school children revealed a prevalence of 14.2% of bronchitis type respiratory symptoms. Logistic regression analysis showed significantly higher odds ratios for bronchitis type symptoms with coal/wood cooker (OR=3.64), living density of >2 persons / room (OR=2.05), moulds (OR=2.01), coal/wood oven (OR=1.80), lack of separate children's room (OR=1.62), smoking and a busy traffic nearby (OR=1.33). Asthma type symptoms were associated with moulds in the children's bedroom (OR=2.21), plastic floor covering (OR=1.66) and living density of >2 persons / room (OR=1.49). Allergic symptoms were reported for every 4th child. These were significantly associated with moulds (OR=1.79), shipboard furniture (OR=1.56), concrete building material (OR=1.32) and a busy traffic nearby (OR=1.30). It is concluded that the prevention of the adverse health effects of indoor air pollution should be supported by the enforcement of the hygienic requirements on safe heating and cooking facilities, prevention of indoor mould growing and avoiding of smoking indoors.

As studied by **Bittencourt (2001),** many different aspects interfere in the environmental climate in the work place, among them: the impact are on air temperature, radiant temperature, air speed and relative humidity but the type of physical activity is also get affected by clothing that is worn.

Human performance is dynamic and is affected by various personal, demographic as well as environmental factors. Although many efforts have been done to find out effect of housing in terms of temperature, relative humidity, age of building structure, years of occupancy, gender, dampness, etc, it is not very much easy to conclude or draw pictures of the association between poor health and housing. Some of the studies showed the relationship of poor housing conditions and emotional stress, respiratory diseases and other symptoms of poor health. In Indian context, the information provided to draw concrete conclusions is negligible and scanty.

Overview of the literature cited in this chapter delineated following points:

- There is a lot of work has been carried out in India on formulation of new organic building material and studying their properties, but the knowledge of facts where the critical factors for carry out optimal actions are limited.

- Many of the problems have a universal aspect, even if the single material or climatic situation is unique. It also reveals important potential links between housing and human performance and generate the data on the same.

- There is a need for conducting further research in the topics like , building material, effect of environment on building materials, building material and indoor environment and building materials and human performance; both in a multidisciplinary aspect and in an international context. Use of the experience from other researches is by that reason of great importance – both in order to inspire and inform.

- Need is revealed for active research work in order to find fundamental understanding of physical factors and biological organisms – especially about the situation in residential building constructions combined with modern organic building materials and use.