ANNEXURE-8

TECHNO-KIT ON OBM

Organic Building Materials

And Residential Constructions

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PREFACE

A stage of saturation has long passed in many countries in exploitation of environment. However, in India, people are reversing back to nature. They have started practicing organic agriculture, herbal products, eco friendly products, sustainable environment, etc.

The emphasis today, worldwide, is on organic products. Eco friendly materials such as wood, clay, thatch, stone, etc. have been used long back to construct homes. Now a days many other natural as well as man made organic building materials (OBM) are being used. Organic materials are perhaps the oldest construction materials but recently they have been noticed by scientists and researchers. Through many generations of use, people have found ways of getting around some of the limitations of naturally organic construction materials. Organic building materials are engineering materials which are mixture of different hydrocarbons sometimes together with sulphur, nitrogen and oxygen derivatives, used in residential constructions.

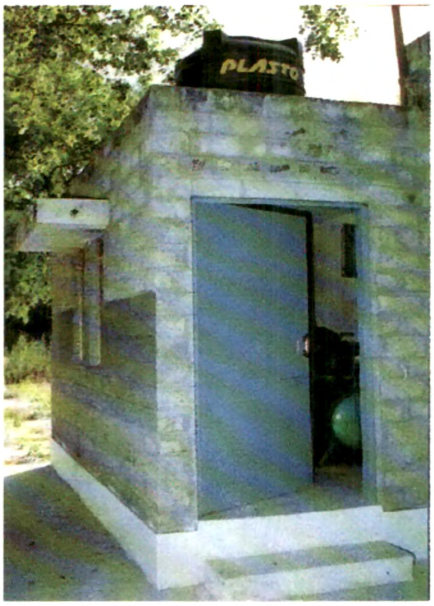
In this context a study of organic building materials used in residential constructions has been conducted. Major emphasis of this investigation is on bringing forth major issues regarding organic building materials, their availability and extent of use, knowledge about OBM, satisfaction, health effects, and effect of the environment.

This booklet attempts to describe issues related with Organic Building Materials, environmental factors affecting indoor housing conditions, traditional residential constructions / state of art in Uttaranchal, health problems due to indoor environment in residential buildings, identification of defective symptoms / deterioration in residential constructions and remedial measures to safeguard OBM and measures to control indoor problems in residential constructions.

CONTENTS

INTRODUCTION

Organic Building Materials are engineering materials, made by a mixture of different hydrocarbons sometimes together with sulphur, nitrogen and oxygen derivatives, used in residential constructions. Organic materials used on or in buildings can be classified according to their use. They include liquid coatings (paints), plastics, sealants, and roofing materials. Wood, although often placed in a separate category, is really an organic building material (Ashton, 1969). Agrawal in 1988 reported that the organic substances contain the element carbon (and usually hydrogen) as a key part of their structure. All living animals and plants are organic.



Along with wood, several organic engineered material have been used from dawn of civilization for its various properties and with the advent of technologies new ones are getting into the way. These materials are used for construction of commercial, academic as well as residential buildings. Their use extends from exterior of a building to floorings, roofing, walls, furnishings, doors, windows, ventilators, electric fittings, plumbing, paints, etc.

Organic building materials are widely used as structural engineering materials for indoor and outdoor applications. In exterior use, wood is subjected to varying environmental conditions resulting in physical deterioration, discolouration, surface roughening, cracking and damages of the micro structure. Weathering affects physical and mechanical properties of wood and also results in premature coating failure. Infestation of pests also results underneath clear finishes, affects coating adhesion and degradates service life of the building materials.

ORGANIC BUILDING MATERIALS

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.

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. 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^{0}F.

- **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^{0}F.

ENVIRONMENTAL FACTORS AFFECTING INDOOR HOUSING CONDITIONS

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. The well-known elements of weather are radiation, moisture, thermal conditions and gases.

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.

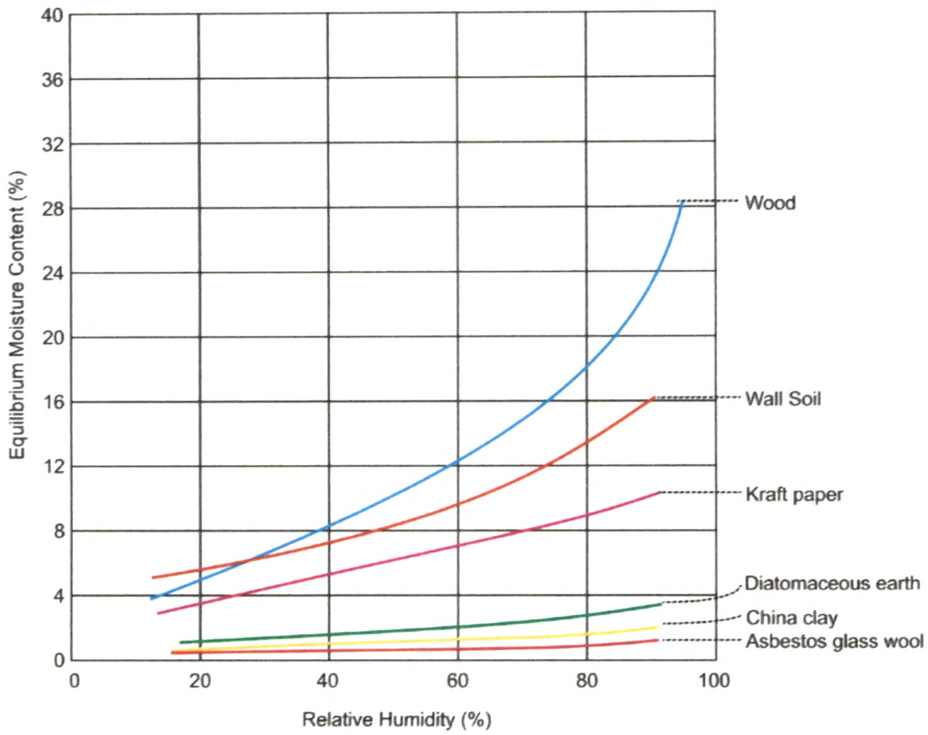
Even though the organic material itself may be resistant, it is possible for UV light to cause undesirable changes if the material is coloured and the colorant, many of which are organic, is not resistant. Fading, which is usually not acceptable, will occur. UV can also cause yellowing. It may alter 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.

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.



Graph1: Moisture Content of some construction materials

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 thermoset 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.

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 1). 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.

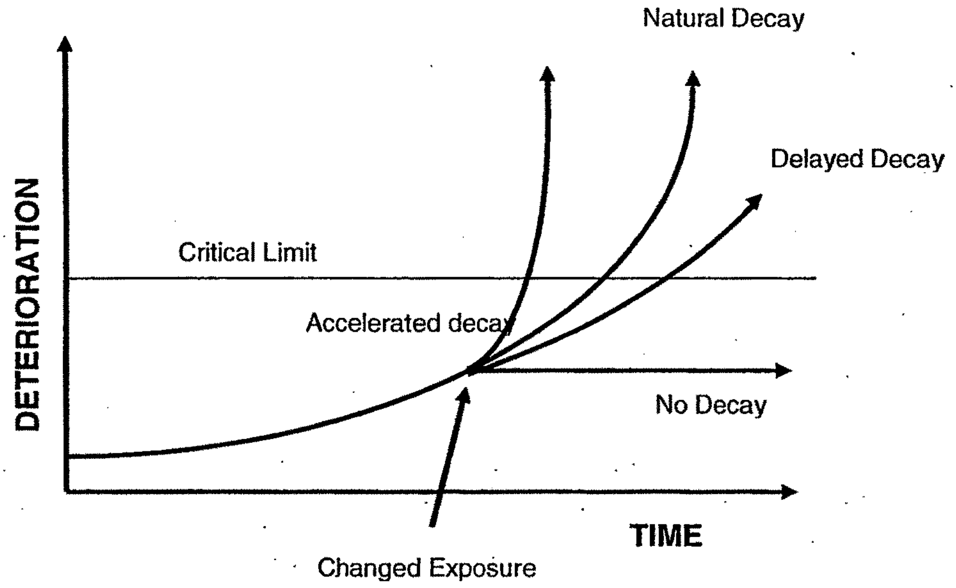


Figure 1: Service life, depending on change of exposure. (Mattson and Oftedal, 2005)

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

1 **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.

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

3 **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.

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

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

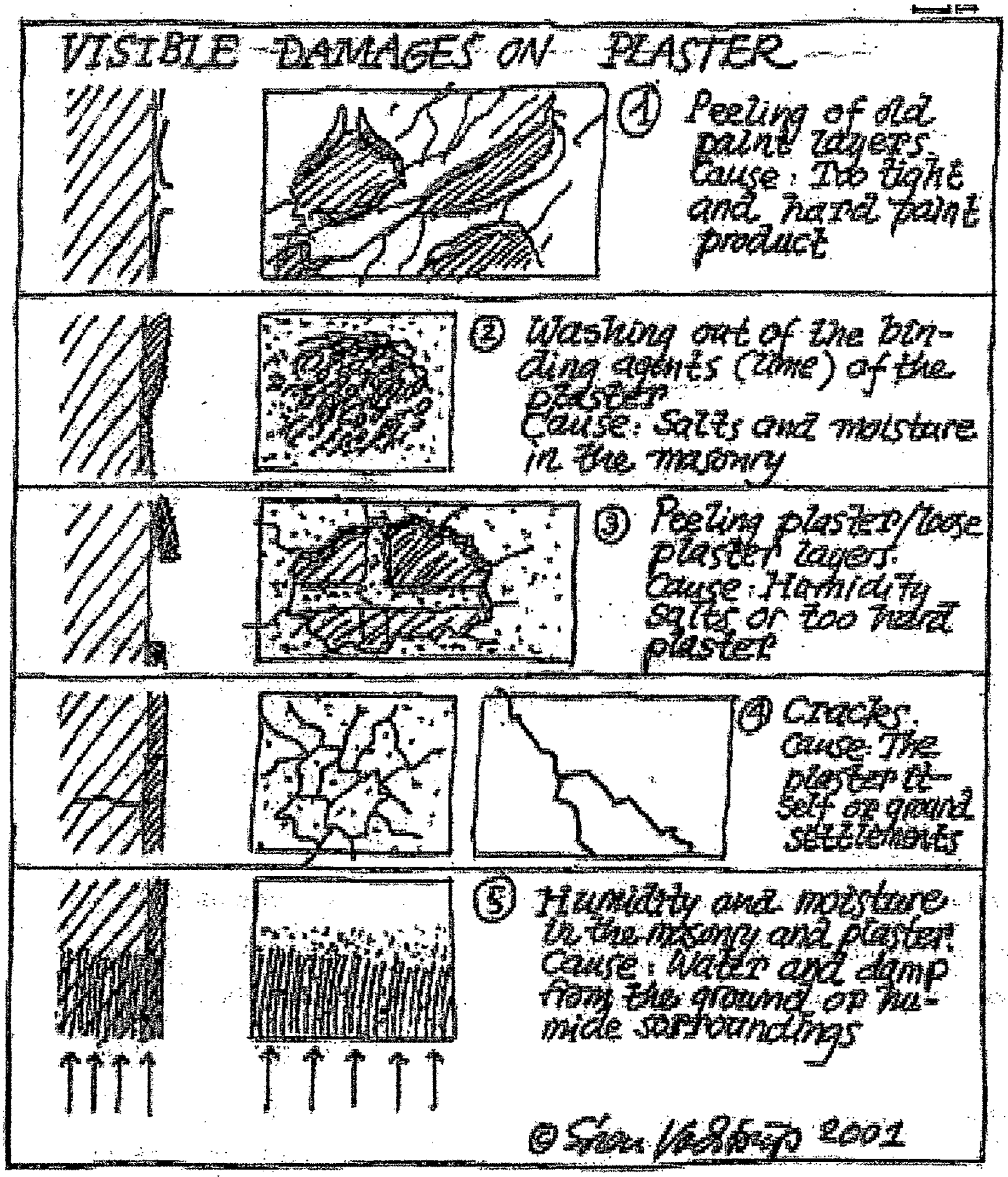


Plate 1: Graphic diagnose sheet of visible deterioration and damages (Vadstrup, 2005)

TRADITIONAL RESIDENTIAL CONSTRUCTIONS / STATE OF ART IN UTTARANCHAL

The spatial organization of a typical house is rather simple, functional and linear. Typologically, in the urban *pols* they are deep wall-to-wall houses with a narrow frontage that opens onto a street. The houses create a dense built environment, as each narrow plot is 100% built up as a result of which a sense of security gets developed. It is basically a deep house-plan with three or four sequential rooms one behind the other. There is typically a small courtyard in the center that brings in light and ventilation. Basements are used for storage and water collection and also for passive cooling in the hot summer months. The optimized and ornate courtyard at the center is an important socio-cultural as well as existential space as a center of household activities.

The wooden facades, a dominating element of the house form, have an intricate ordering mechanism, articulated elements and profuse carvings. They are often an expression of the socio-economic status of the owners. The aesthetic vocabulary of I making is created with horizontal bands and vertical fenestrations. There is composite construction in brick and wood. At times, burnt brick was used with mud mortar. Wooden structure is evolved through the beam and joist system with made-up floors. The internal courtyard is also a spatial aesthetic experience with the woodwork contributing a great deal. The finely carved columns, brackets and balconies are predominant elements.

a. Use of Wood for Structure and for Wooden Elements

One of the main uses of wood is as a structural material in the construction of the house. Timber is used in conjunction with brick or stonewalls to create a composite structure. A wooden frame of joists and columns is made to support the building. If the spans are large then the columns are embedded in the walls otherwise they are left free. Wooden brackets are used to support floor projections that acted as weather shields. The brackets were highly ornamented, as were the wooden column capitals.

The main charm of the woodwork was, however, in the making of the front façade of the houses. The order imposed through standardized or similar scales, the proportioning system shared by them, the common building materials/techniques and elements gave a unified characteristic and an aesthetic richness to the building facades. Often, a balcony was cantilevered while being supported on struts embedded in the wall. The balcony was a magnificent part of the façade. Delicately carved doors and windows formed other important elements in the making of the façade. It was a matter of prestige to have a decorated entrance door that often became massive and elaborate. Greatest care and expense was lavished on the front door. Geometrical and floral patterns and motifs dominated the ornamentations.

b. Craftsmanship in Woodwork

Uttaranchal is a wood-rich region. The resultant woodwork was unique in scale and quality. It was predominantly used in I making, framing, floors and ornamentation. In spite of typological standardization, uniqueness was brought in as each craftsman was allowed to leave the imprint of his artistry in the creation of individual elements and motifs within the overall formal order.

The traditional building process was reinforced by a guild system of craftsmen during that period. Because a craftsman spent an entire lifetime working with one single material and fabricating artifacts of similar types, he became a master of that particular material and object making. The building process then benefited from his intimate knowledge as well as versatility. Traditional knowledge was handed down from generation to generation. Being in a hereditary occupation, the artisan achieved perfection of his art through vigorous apprenticeship and careful preservation of tradition. Thus the art of building became a manifestation of their shared culture and heritage. They were able to easily adapt to different materials, motifs and styles of fashioning.

c. Service Life for Building Materials

1. Wooden Materials

The most used wood species in traditional buildings are pine and spruce. Only exceptionally, other species such as oak and aspen are used. Due to long-term exposure for humidity, sooner or later the decay has reached a critical limit for the service life of the materials. The critical limit is usually connected to technical properties, but other factors, such as antiquarian, cosmetic or economical aspects, might be taken into consideration. The decay of wood due to natural exposure is more or less predictable. The service life are in many cases for buildings and single building materials regarded to be pretty long – despite the relatively poor service life for pine- and spruce wood compared to hardwood. 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. 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. Stone materials

It has been done little about the bio-deterioration of stone material. However, during the latest years, the interest for protection of rock carvings (from the bronze age, 3.-5.000 years BC) has increased the focus on this topic. Decay of different kind of stone materials by microorganisms are proven, with a special emphasis on crustaceous lichens – even if also bacteria and fungi are playing an important role. The decay occurs normally slowly, but can under certain circumstances happen relatively fast – especially in combination of physical factors (e.g. fluctuation of temperature – where the freezing of water is essential) and influence of chemicals and mechanical exposure.

Plate 14: Use of stone in stairs of the house

3. Damages in flooded houses

This implied investigations of differences in biodeterioration (mould and decay fungi) in traditional and modern buildings with water damages caused by flood. Ongoing project with possibility for extensive moisture measurements and studies of development of mould growth, attack of wood-decaying organisms and insects.

4. Damages due to change of constructions (thermal insulation and establishing of damp-proof layers).

It is shown that some insulation materials can act as a "fertilizer" for *Serpula lacrymans*. Another problem with inserting thermal insulation is the change of temperature and humidity, which can initiate growth of mould and decay fungi. We have also shown the critical effects of inserting damp-proof layers in existing constructions.

5. **Moisture balance in brick walls with different surface coatings**

Due to humidity measurements through a year, it is shown that it is relatively small differences in humidity in the inner part of brick constructions (where end of floor beams and other wooden material are inserted). This implies that it is not critical for the construction, whether it is used traditional or modern surface treatment or plaster – even if it can be of major concern regarding antiquarian aspects.

6. **Decay in log buildings due to surface treatment**

Extensive humidity measurements have shown that the moisture content in logs (both new and old) is varying, depending on exposure and paint system. In some cases the moisture content can reach critical limits for growth of wood-decaying fungi.

7. **Stored materials and products**

The problem with deterioration of paper materials is mainly connected to storage in damp buildings, or at least buildings with poor ventilation and without heating. Under such conditions, there can be long periods when the relative humidity is high enough for mould growth and attack of various insects. Similar damages as for paper are also a problem for other stored materials (e.g. textiles, leather) in open-air museums and other unheated buildings.

HEALTH PROBLEMS DUE TO INDOOR ENVIRONMENT IN RESIDENTIAL BUILDINGS

Health effects from indoor air pollutants may be experienced soon after exposure or, possibly, years later.

Immediate effects may show up after a single exposure or repeated exposures. These include irritation of the eyes, nose, and throat, headaches, dizziness, and fatigue. Such immediate effects are usually short-term and treatable. Sometimes the treatment is simply eliminating the person's exposure to the source of the pollution, if it can be identified. Symptoms of some diseases, including asthma, hypersensitivity pneumonitis, and humidifier fever, may also show up soon after exposure to some indoor air pollutants.

The likelihood of immediate reactions to indoor air pollutants depends on several factors. Age and preexisting medical conditions are two important influences. In other cases, whether a person reacts to a pollutant depends on individual sensitivity, which varies tremendously from person to person. Some people can become sensitized to biological pollutants after repeated exposures, and it appears that some people can become sensitized to chemical pollutants as well.

Certain immediate effects are similar to those from colds or other viral diseases, so it is often difficult to determine if the symptoms are a result of exposure to indoor air pollution. For this reason, it is important to pay attention to the time and place the symptoms occur. If the symptoms fade or go away when a person is away from the home and return when the person returns, an effort should be made to identify indoor air sources that may be possible causes. Some effects may be made worse by an inadequate supply of outdoor air or from the heating, cooling, or humidity conditions prevalent in the home.

Other health effects may show up either years after exposure has occurred or only after long or repeated periods of exposure. These effects, which include some respiratory diseases, heart disease, and cancer, can be severely debilitating or fatal. It is prudent to try to improve the indoor air quality in your home even if symptoms are not noticeable.

While pollutants commonly found in indoor air are responsible for many harmful effects, there is considerable uncertainty about what concentrations or periods of exposure are necessary to produce specific health problems. People also react very differently to exposure to indoor air pollutants. Further research is needed to better understand which health effects occur after exposure to the average pollutant concentrations found in homes and which occur from the higher concentrations that occur for short periods of time.

The ability of organic chemicals to cause health effects varies greatly from those that are highly toxic, to those with no known health effect. As with other pollutants, the extent and nature of the health effect will depend on many factors including level of exposure and length of time exposed. Eye and respiratory tract irritation, headaches, dizziness, visual disorders, and memory impairment are among the immediate symptoms that some people have experienced soon after exposure to some organics. At present, not much is known about what health effects occur from the levels of organics usually found in homes. Many organic compounds are known to cause cancer in animals; some are suspected of causing, or are known to cause, cancer in humans. Following are some health effects reported by the residents living in residential constructions:

- Sneezing
- Dizziness
- Cough
- Headache
- Nausea
- Fatigue
- Excitement
- Eye irritation
- Effect on hearing
- Throat irritation
- Mental fatigue
- Chest tightness
- Shortness of breath
- Wheeze
- Nose bleeds
- Dry skin
- Skin rash
- Lethargy

- Skin irritation
- Effect on visibility
- Symptoms of humidifier fever

There are some chronic syndromes those can be identified as severe diseases in residents due to building materials

A. Sick building syndrome

- Symptoms of eye irritation
- Symptoms of throat irritation
- Symptoms of nose irritation
- Symptoms of mucosa of skin
- Mental fatigue
- Arythema

B. Building related illness

- Asthama like symptoms
- Legionnair's disease
- Hyper sensitivity
- Humidifier fever

C. Multiple chemical sensitivity

- Extreme dust sensitivity
- Chronic fatigue
- Nausea
- Headache

IDENTIFICATION OF DEFECTIVE SYMPTOMS / DETERIORATION IN RESIDENTIAL CONSTRUCTIONS

a. Identifying Air Quality Problems

Some health effects can be useful indicators of an indoor air quality problem, especially if they appear after a person moves to a new residence, remodels or refurnishes a home, or treats a home with pesticides. If you think that you have symptoms that may be related to your home environment, discuss them with your doctor or your local health department to see if they could be caused by indoor air pollution. You may also want to consult a board-certified allergist or an occupational medicine specialist for answers to your questions.

Another way to judge whether your home has or could develop indoor air problems is to identify potential sources of indoor air pollution. Although the presence of such sources does not necessarily mean that you have an indoor air quality problem, being aware of the type and number of potential sources is an important step toward assessing the air quality in your home.

A third way to decide whether your home may have poor indoor air quality is to look at your lifestyle and activities. Human activities can be significant sources of indoor air pollution. Finally, look for signs of problems with the ventilation in your home. Signs that can indicate your home may not have enough ventilation include moisture condensation on windows or walls, smelly or stuffy air, dirty central heating and air cooling equipment, and areas where books, shoes, or other items become moldy. To detect odors in your home, step outside for a few minutes, and then upon reentering your home, note whether odors are noticeable.

b. Measuring Pollutant Levels

The federal government recommends that you measure the level of radon in your home. Without measurements there is no way to tell whether radon is present because it is a colorless, odorless, radioactive gas. Inexpensive devices are available for measuring radon. Environment Protection Agency provides guidance as to risks associated with different levels of exposure and when the public should consider corrective action. There are specific mitigation techniques that have proven effective in reducing levels of radon in the home. For pollutants other than radon, measurements are most appropriate when there are either health symptoms or signs of poor ventilation and specific sources or pollutants have been identified as possible causes of indoor air quality problems. Testing for many pollutants can be expensive. Before monitoring your home for pollutants besides radon, consult your state or local health department or professionals who have experience in solving indoor air quality problems in non industrial buildings.

c. Weatherizing Your Home

The federal government recommends that homes be weatherized in order to reduce the amount of energy needed for heating and cooling. While weatherization is underway, however, steps should also be taken to minimize pollution from sources inside the home. In addition, residents should be alert to the emergence of signs of inadequate ventilation, such as stuffy air, moisture condensation on cold surfaces, or mold and mildew growth. Additional weatherization measures should not be undertaken until these problems have been corrected.

Weatherization generally does not cause indoor air problems by adding new pollutants to the air. (There are a few exceptions, such as caulking, that can sometimes emit pollutants.) However, measures such as installing storm windows, weather stripping, caulking, and blown-in wall insulation can reduce the amount of outdoor air infiltrating into a home. Consequently, after weatherization, concentrations of indoor air pollutants from sources inside the home can increase.

d. Checklist of observable defective symptoms in home

Making observations in the home from time to time can help in making corrective measures. Proper and timely maintenance of the home helps in improvement of indoor air quality. A brief checklist to help in observation is as under:

i. Roof

- Rot
- Granular surface
- Loosen pavings
- No grating
- Splits
- Crumbled on surface
- Dampness
- Bubbles on surface

- Dirt
- Infestation
- Stains

ii. Walls

- Cracks
- Twisted / Curled
- Fractured
- Dry dirty patch
- Damp rising on internal walls
- Rot
- Dirty Spots
- Dampness
- Sagging timber lining

iii. Floors & Staircases (Timber)

- Rot
- Saw dust
- Stains
- 1st floor unstable under foot cracks
- Squeaks the staircases
- Small holes
- White spongy under floor covering
- Board crack underfoot
- Bay dips outward
- Long filament growth
- Olive green or brown fruiting body on surfaces
- Tread fall away
- Dirt

iv. Internal finishes

- **Plaster**
    - Crack
    - Dry & crumbly
    - Bulging
    - Blister or small crater
    - Soft & Crumbly
    - Dampness
    - Pinholes in joinery
- **Painting**
    - Bittiness
    - Cissing
    - Grinning
    - Shriveling
    - Brush marks
    - Efflorescence
    - Poor opacity
    - Blooming
    - Drying trouble
    - Mould
    - Bleeding
    - Crazing
    - Loss of gloss
    - Saponification

- Blistering
- Running
- Misses
- Chalking
- Flaking
- Sheeriness

v. Services

- Leakage
- Encrustation
- Water stain
- Lack of temp.
- Spots
- Noisy
- Fungus
- Supply sluggish
- Excessive joints
- Smell of heating

Cracking and flaking off due to dampness in building

REMEDIAL MEASURES TO SAFEGUARD ORGANIC BUILDING MATERIALS

a. Protection of rock carvings against lichens/micro fungi

Rock carvings are overgrown by microorganisms. This biological activity leads to some decay of the stone and it is therefore often desirable to remove the organisms. Traditionally, this removal has implied unacceptable use of chemicals (formaldehyde) and mechanical methods that has lead to further damage of the carvings. Our experiments showed that specific covering of the surface in few months completely can remove crustaceous lichens and stain fungi – both on the surface and 3-4 mm down into the stone.

b. Protection against wood-decaying fungi and other microorganisms in wood with soil contact

Deteriorated wood are protected against further damage development by keeping the wood wet and in contact with high salt concentrations. It is also shown that salt has a preservative effect on new wood samples.

c. Environmental friendly protection against house longhorn beetles

House longhorn beetles attacks are often wrong evaluated because of lack of knowledge. This often leads to unnecessarily large restorations. Systematic registrations of house longhorn beetle attacks and registrations of eventual further development of the attacks would therefore be useful.

MEASURES TO CONTROL INDOOR PROBLEMS IN RESIDENTIAL CONSTRUCTIONS

1. **Moisture:** Eliminate the source of moisture. Install and use exhaust fans. Keep an eye out for condensation on walls, standing water on the floor or sewage leaks. To keep basement dry, prevent outside water sources from entering (install roof gutters and downspouts, do not water close to foundation, grade soil away from home, apply water proofing sealants to basement interior walls). For standing water, consider installing a sump pump. Use dehumidifier if necessary.

2. **Air-Conditioner:** Empty and clean water tray often. Follow all service and maintenance procedures, including changing filter.

3. **Moisture from bathing, clothes washing, cooking, dishwasher use, etc.:** Install and use exhaust fans. Fix plumbing leaks and all sources of moisture intrusion right away.

4. **Humidifier:** Use and clean according to manufacturer's directions. Refill with fresh, distilled water daily. Do not use tap water since it may release small particles and minerals into the air that can be irritating.

5. **Carpet, Textiles and Bedding:** To help decrease biological pollutants, such as dust mites, clean and vacuum house and all "fuzzy" textiles such as carpet and upholstered furniture. Deep cleaning should occur at least once a year with a system certified to show greater than 98% extraction efficiency for allergens, soil, and molds. Wash bedding in hot water above 130° F. Keep home humidity levels below 60%. Bedding can be encased with plastics or other moisture proof materials. Stay away from biocide treated materials.

6. **Animals:** Keep pets outdoors as often as possible. Clean entire house regularly, concentrating on those areas where pets spend most of their time. Make sure vacuum system is efficient for removal of pet allergens.

7. **Clothes dryer:** Regularly dispose of lint around and under dryer. Provide make-up air for combustion of gas. Exhaust dryer directly to the outside to get rid of combustion products and moisture. Dry clothes on an outside line instead.

8. **Furnishings and Construction materials:** Clean and dry or remove water-damaged materials promptly within 24 hours. Use low-emitting materials only that have been certified. Following introduction of new products into the home, open doors and windows, or use window fans to air out the house. New products will often have odors and chemicals released that should go away within 48 ours or no later than a week.

9. **Pressed wood cabinets, Shelving or Furniture:** Coat pressed wood products with polyurethane or laminates to reduce formaldehyde emissions. Maintain moderate temperatures (80° F maximum) and humidity (about 45%). When purchasing new cabinets, select solid wood or metal cabinets.

10. **Draperies and Upholstered Furniture:** Before hanging new drapes or bringing them into the house, air them out. Vacuum or clean often so dust and other pollutants will not accumulate on them.

11. **Office equipment:** Purchase products that have been certified to have low emissions and follow operating and maintenance instructions. Use only media (inks, toners, papers) approved by the manufacturer. Make sure proper ventilation is supplied around the product and those new products are aired out with open windows and opened doors. If the product has an ozone and VOC filter, make sure that it is replaced according to the instructions.

12. **Air Cleaners:** Use only those that do not emit ozone or biocides in the air. Follow operating and maintenance instructions.

13. **Household cleaners:** Select non-aerosol and non-toxic products with minimal chemical solvent and odor release. Use, apply, store and

dispose according to manufacturer's directions. Never mix products together. Buy only the amount you need and use it up completely.

14. **Personal care products:** Select fragrance-free, non-aerosol products with minimal chemical solvent or formaldehyde release.

15. **Paints, Solvents and Solvent Materials:** Store them in a well-ventilated area, preferably a freestanding shed and outside of the house and garage.

16. **Throw away partially full containers of old or unneeded chemicals safely:** Because gases can leak even from closed containers, this single step could help lower concentrations of organic chemicals in your home. (Be sure that materials you decide to keep are stored not only in a well-ventilated area but are also safely out of reach of children.) Do not simply toss these unwanted products in the garbage can. Find out if your local government or any organization in your community sponsors special days for the collection of toxic household wastes. If such days are available, use them to dispose of the unwanted containers safely. If no such collection days are available, think about organizing one.

17. **Buy limited quantities:** If you use products only occasionally or seasonally, such as paints, paint strippers, and kerosene for space heaters or gasoline for lawn mowers, buy only as much as you will use right away.

18. **Keep exposures to emissions from products containing methylene chloride to a minimum:** Consumer products that contain methylene chloride include paint strippers, adhesive removers, and aerosol spray paints. Methylene chloride is known to cause cancer in animals. Also, methylene chloride is converted to carbon monoxide in the body and can cause symptoms associated with exposure to carbon monoxide. Carefully read the labels containing health hazard information and cautions on the proper use of these products. Use products that

contain methylene chloride outdoors when possible; use indoors only if the area is well ventilated.

19. **Keep exposure to benzene to a minimum:** Benzene is a known human carcinogen. The main indoor sources of this chemical are environmental tobacco smoke, stored fuels and paint supplies, and automobile emissions in attached garages. Actions that will reduce benzene exposure include eliminating smoking within the home, providing for maximum ventilation during painting, and discarding paint supplies and special fuels that will not be used immediately.

20. **Keep exposure to perchloroethylene emissions to a minimum:** Perchloroethylene is the chemical most widely used in dry cleaning. Its sources are household products including: paints, paint strippers, and other solvents; wood preservatives; aerosol sprays; cleansers and disinfectants; moth repellents and air fresheners; stored fuels and automotive products; hobby supplies; dry-cleaned clothing.

21. **Pesticides and Herbicides:** The best advice is not to use these indoors. If required, have application done by an experienced, knowledgeable, and accredited professional. Check and ensure that approved materials are being used, and follow their recommendations for safety. Vacate house during application and air out for some period. Do not use or apply around food, eating or cooking utensils, children, or pets. If used outside, make sure that shoes are removed and foot mats are used to prevent contamination of indoor flooring. Pets can also carry in residues.

22. **Moth repellents:** Instead of using moth repellents, store clothes in cedar lined chests or closets. Keep humidity and temperature controlled in the home and vacuum dormant rug or carpet areas (such as under tables) periodically. Stay away from the use of other pesticides or pesticide treated materials.

23. **Dry-cleaned clothes:** Wear clothes that do not need dry-cleaning. For dry-cleaned articles, air them out before bringing them indoors. Choose

a cleaner who minimizes use of solvents and airs clothes before enclosing in plastic.

24. **Car or Small Engine Exhaust:** Never leave vehicles, lawn mowers, snowmobiles, etc. running in the garage-even with the garage door open. The solution is to seal off the house from the garage.

25. **Environmental Tobacco Smoke:** Do not smoke in your home or permit others to do so (especially near children).

26. **Gas or other fuel-burning appliances:** Have your heating system and water heater (including gas piping and venting) inspected every year. Check chimney for obstructions that may block the exhaust leaving the appliances. Clean regularly around the furnace and water heater. Repair fuel or gas leaks immediately. Follow service and maintenance guidance, including changing filters. If you suspect carbon monoxide poisoning or a fuel leak, get out of your home right away. Call for help from a mobile phone or neighbor's house.

27. **Gas or kerosene space heater:** Never use unvented kerosene or gas space heaters. In rooms where a heater is located, provide fresh air by opening a door to the rest of the house, turning on an exhaust fan, or opening a window slightly.

28. **Fireplaces:** Open flue when building a fire in the fireplace. Have the flue and chimney inspected every year.

29. **Radon:** Test your home for radon. That is the only way to know if you have it.

30. **Pipe wrap and furnace Insulation containing Asbestos:** Check insulation every so often to make sure it is not damaged or deteriorating. Do not cut, rip, sand or remove any asbestos-containing materials.

31. **Floor tiles:** Every so often, inspect them for damage or deterioration. Do not cut, rip, sand or remove any asbestos-containing materials.

32. **Follow label instructions carefully:** Potentially hazardous products often have warnings aimed at reducing exposure of the user. For example, if a label says to use the product in a well-ventilated area, go outdoors or in areas equipped with an exhaust fan to use it. Otherwise, open up windows to provide the maximum amount of outdoor air possible.