Polymer-based Building Materials: Effects of Quality on Durability

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ABSTRACT

Polymer is the main substance of plastic. Monomers are the 'building blocks', polymer is the completed plastic and the reaction is called polymerization. During production processes, as well as oil-based chemicals, chlorine, hydrochloric acid, fluorine, nitrogen, oxygen and sulphur are the substances used. Nearly all plastics include additives like plasticizers, pigments, stabilizers against solar radiation, preservatives and perfumes. Plastic is a substance that contains natural or synthetic high molecular organic material which can be liquefied and thereby cast in specific moulds.

Quality can be defined as the appropriateness level of a product to the desires of the consumer. The quality of a product or a complete building or other construction is the totality of its attributes. Quality enables to perform a stated task or to fulfil a given need satisfactorily for an acceptance period of time. If the material has low level of quality, durability of the material will be shortened. Plastic building materials are used in floors, roofs and walls. It is difficult and expensive to repair or replace them. Plastics should have a functional life-span at least 50 years equivalent to other materials in the building. It is unlikely that any of today's plastics can satisfy such conditions.

In this paper, the meaning of quality will be defined again through the view of polymer based (plastics) building materials. Quality properties which will enable the durability of polymer based materials with a more functional life span will be discussed. The last developments in plastics industry and their effects on durability will also be reported.

KEYWORDS

Polymer, Plastic, Building material, Quality, Durability

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1 INTRODUCTION

Throughout the 1990s, polymer based building materials, especially plastics, have been used widely in construction industry. Superior strength in weight performance, corrosion resistance, environmental stability, insulation properties, lower cost are the main properties of polymer based building materials.

Although, polymer based building materials have some important superior properties compared to traditional materials, they have some disadvantages, like their flammability and smoke toxity. However employing additives or combining with other materials, helps plastics gaining superior properties. Quality level of polymer based building materials can be evaluated through the new results. Durability of the material will be affected also by the quality level of the material.

2 POLYMER BASED BUILDING MATERIALS

Polymers are organic compounds which are the main substance of plastic. Monomers are the 'building blocks', polymer is the completed plastic and the reaction is called polymerization. During production processes, as well as oil-based chemicals, chlorine, hydrochloric acid, fluorine, nitrogen, oxygen and sulphur are the other substances used. Nearly all plastics include additives like plasticizers, pigments, stabilizers against solar radiation, preservatives and perfumes. Plastic is a substance that contains natural or synthetic high molecular organic material which can be liquefied and thereby cast in specific moulds [Berge 2001].

Plastics were first used as ornament, superficial finish, or as secondary parts for enclousure systems, in building and construction. Although, plastics are in construction industry as a wider scope of uses such as interior finishes, glazing, plumbing fixtures and even structural components today, only recently they began to gain respect and appreciation as a viable primary material. Having a lower fire-rating and limited usage in applications of requiring fire resistance are the weakness of plastics compared to other construction materials. However, there are some advantages plastics can offer like they are lightweight, lower in cost, resistant to corrosion and moisture, can be relatively strong and are readily shaped. One of the other disadvanges of plastics was their being short-lived fad that is brittle and prone to discolor, but has recently been revised due to enormous advances in the plastics industry, which has manufactured unprecendented variety of new products with improved physical properties. Since the material is intrinsically man-made, there is no limit for the charasteristics and expanding will continue [Bell 2006].

Plastics can be divided into two basic categories: thermo plastics and thermosetting plastics. Thermosetting plastics and thermoplastics are both used in building. Thermosetting plastics are generally harder and stronger than thermoplastics. Adhesives, laminates, rigid foam insulation, waterproofing membrances and window frames are typical applications of thermosetting plastics. Polyvinyl chloride (PVC), polycarbonate and acrylic are the three types of thermoplastics which are most often used in building construction. PVC is the most commonly used plastic in building construction. Resistance to water, and some chemicals, low cost and resistance to tearing are the main charasteristics of PVC. [Bell 2006] When produced as a foam, many plastics have high thermal insulation properties and good water- and vapour-proofing properties. Paint, sheeting, paper, sealing strips and mastics are the guises plastic can take as a sealant. Polyisobutyl, polyehylene and PVC are the three plastics used for sheeting. Sheetings can be used as damp-proofing for foundations, vapour barrier or moisture-proofing. A mastic has to fulfill the conditions of constant elasticity and durability. Polysulphide, silicone, polyurethane and various acrylic substances are used as mastic. The composition is usually based on at least five chemical substances with at least eight different additives. Sealing strips are the materials used mainly between the sheets of glass in window and door reveals. Polyurethane, polyamide, PVC, ethylene-propylene rubber, chloroprene rubber and silicone rubber are the important plastics used in sealing strips. The products include different additives also. Polystyrene, polyurethane and urea formaldehyde are the plastics used to produce different insulation materials [Berge 2001].

Plastics is rarely used as a structural material in building. In the western world, a large amount of unspecified plastic waste exists now which can be possible raw material for simple structural elements. If supporting substances are added in proportions of 10-15 percent, polystrene waste can be cast into solid beams and columns. The components are suitable for sawing and nailing and the structural properties are approximately the same as timber. [Berge 2001] For structural applications, pultruded glass-fiber-reinforced polymer (GFRP) profiles have a great potential; the higher strength to weight ratio, the lower weight, the electromagnetic transparency, the ease of installation, the lower maintenance requirements, and the improved durability in aggressive environments are the advantages over traditional materials. Although (GFRP) profiles have been used mainly in nonstructural or secondary structural elements up to now, such as ladders, handrails and pavement grids, according to the results of researches, they offer a very good mechanical performance and lightness, as well as good durability charasteristics, compared with those of traditional structural materials [Correia *et al*. 2006].

Crack repair systems have been used for many years and polymer based building materials are one of the most common crack repair materials. Epoxy resins generally have very good bonding and durability characters that commonly used repair materials. According to Calder and Thompson the overall structural performance of reinforced concrete slabs repaired using epoxy resin injection performed best compared to other materials such as polyester and methl methacrylate resins. The use of carbon fiber reinforced polymers (CFRP) is a new development in the repair and the rehabilitation of reinforced concrete. In recent years, the applications of these materials to structural repair and retrofit have grown significantly. Carbon fiber reinforced polymers fabrics offer supperior performance such as resistance to corrosion, and a high stiffness-to-weight ratio. [Ekenel & Myers 2007] As the results of researches with advanced composites had shown that plastic composites were more durable than steel and conrete and also they are lightweighted, energy-absorbent, less corrosive and low cost new methods to strenthen bridges, buildings and other forms of civil infrastructure with plastic composites are being developed. According the results plastic ‘wraps’, which are only a few millimetres thick and consist of a fibreglass-graphitecomposite, around concrete structures can increase their strength [Jones 2007].

3 QUALITY OF POLYMER BASED BUILDING MATERIALS

Construction quality is a measure of the level of meeting a particular work the requirements demanded by the building project. [Mora 2007] The quality of a product or a complete building or other construction is the totality of its attributes. Quality enables to perform a stated task or to fulfil a given need satisfactorily for an accepted period of time. If the material has low level of quality, durability of the material will be affected negatively. During the construction process by ensuring to use materials of the same durability, the use of raw materials is reduced, by producing more durable products. Therefore it is possible not sacrificing better quality components in a building when there is decay elsewhere. When there are any materials with less quality, it is important to be easily replaced while the more durable materials can be dismantled for re-use or recycling in the case of demolition. There is a clear advantage in using robust materials and allowing buildings lasting as long as possible. [Berge 2001] Energy required to produce the material, CO2 emissions resulting from the manufacture of the material, toxity of the material are some of the factors determined by the quality of the materials. Like quarry pit, wood taken from forest, oil spills from an oil well, the impact on the local environment resulting from the extraction of the material is the other factor of quality of the materials. Degree of pollution resulting from the material at the end of itsuseful life, lifetime of the material and its potential for reuse if the building is demolished are the other factors that can be taken into consideration while determining quality of a material. [Roaf *et al.* 2003].

Plastic composite building materials obtain much of their versatility because they can be engineered to provide specific performance charasteristics including durability, light weight, corrosion resistance, high strength, and low maintenance requirements. In cooler climates, fiber-reinforced polymers (FRP)

could increase the use of concrete in architectural cast fences. As the thread of freeze-thaw and corrosion require substantial concrete coverage forrebar protection, concrete is not a suitable material for thin wall structures. FRP composites could present a solution, when a structural element, such as a wall or beam can benefit from additional support. A combination of wood fibers and plastics is wood-plastic composites (WPCs). Their durability and weather-resistance can be appropriate for outdoor environments. Wood-plastic composites (WPCs) are commonly used, where durability is an important performance attribute. In order to improve processing and performance, small amounts of other materials can be added to wood-plastic composites (WPCs) as with inorganic-fiber composites. WPC lumber rarely rots, cracks, warps, or splinters, when properly manufactured and installed. WPC are typicaly stain resistant, waterproof, ultraviolet (UV) light-resistance and impervious to insects and can be made strong enough for applications such as load-bearing deck boards. A good dimensional stability and a lower coefficient of expansion than solid plastics are the other properties WPCs tend to have [Krebs 2006].

Plastics will burn, like all organic materials. As such, increasing the temparature necessary before ignition and/or lower the rate of burning, plastics used in construction contain fire-retarding. The various building codes typically have regulations require specific fire performance characteristics that deal with plastics. These characteristics are for fire/flame retardation and safety. Today's plastic construction materials, when used in the proper application and correctly installed, can meet or exceed the fire performance charasteristics required by most codes and standarts, can help provide a nice living environment by performing their intended function. Different performance requirements are specified, when foam plastic materials are installed on the exterior of buildings. As the foam plastic insulation material contribute to upward flame spread over the surface or within the exterior wall, additional specialized tests are also specified to prevent. [Parker & Beitel 2006]

Including acrylic, some interesting products have left their mark in recent years. Acrylic plastic products are known with the virtue of material lying in its clarity and ultraviolet (UV)- resistant attributes. When the material is extruded, thin UV-resistant coatings can be applied to polycarbonate, offering enhanced protection for performance and aesthetics. Besides, light-diffusing charasteristic of the celular structure can leave any strach or dirt almost undetectable. A simple hosing or pressure-washing usually suffices, when cleaning is desired. [Bonenfant 2006] Vinyl can be easily kept clean and disinfected, since it can be washed or scrubbed. This is an important consideration for healthcare projects the spreading of germs and bacteria must be minimised. Vinyl can be versatile and durable. Strong and scratch-resistant vinyl products are continually becoming easier to apply, partly due to bette pastes. Especially for high-traffic areas, vinyl coverings are ideally suited. Vinyl becomes a wide variety of price and design options. [Jacop 2006] In window applications, although other plastics are also employed, PVC is often used as the thermoplastic matric. 80- to 200- mesh wood fiber which is a wood-filled PVC product is usually employed in windows and doors, offers thermal stability, moisture resistance, and stiffness. Wood flour have been combined with both vinyl and polyolefin to form exterior trim in new exterior applications that resists rot and weathering. A wide range of design can be shaped by the resulting material that typically do not require painting or the use of special cleaning agents [Krebs 2006].

Polycarbonate, among the first window glazing materials certified, can resist the impact of a 2.4m. (8-ft) long 2x4 fired from an air cannon at 55 km/h (34 mph). A polycarbonate barrel-vault skylight was impact load and high-pressure winds. Polycarbonate can offer opportunuties for day lighting, in addition to impact resistance. Daylighting is not only a matter of bringing in the sun's light but also efficient systems must insulate well [Bonenfant 2006].

4 DURABILTY OF POLYMER BASED BUILDING MATERIALS

Durability is an ability of a building or a material to maintain its performance over time and use. It can be measured in terms of the time until some loss of function occurs that renders the service provided

unacceptible. It depends on the degrading effects of the service and the environment to which it is exposed, it is not a fundamental property of a material. Refering to service, life, is more appropriate, as this properly implies the effects of the particular conditions of service. Being long lasting, can reduce maintenance and repair costs, and often cost-effective from a life-cycle perspective are advantages of durable materials and building systems. Minimized disruption of building operations and environmental benefits resulting from the reduced disposal and replacement of materials.

Durability is not only a quantifiable technical property, but has also an aesthetic and fashionable aspect. Designing a product that can outlast the swings of fashion is also quite a challenge. Rather than a maximum durability, it is also important to consider an optimal durability, especially with technical equipment. The lifespan of a material depends on mainly four factors which are the material itself, its physical structure and chemical composition; construction and its execution, where and how the material is fitted into the building; the local environment, the climatic and other chemical or physical conditions; maintenance and management. [Berge 2001] Durable materials will not need to be replaced or repaired as frequently, so the raw materials, energy, and environmental impacts invested in them can be spread out over more time. Durable materials provides a long period of time to amortize the environmental and economic costs that were incurred in building it. Durability is an issue of water management to a significant extent. The ratio of durability problems in buildings are fully 80 percent about moisture. By causing materials to expand and contract, thermal stress can reduce durability. This can affect, for example, long-term window performance. Making windows leaking over time, including vinyl and aluminum certain frame materials expand and contract at a higher rate than glass. Roofing materials are also affected by high roof temparatures. Ultraviolet light (UV) degrades most plastics. Along with heat, degradition of roofing materials is a major problem. Including vinyl siding, although in some cases UV stabilizers themselves carry environmental burdens, plastics that are used outdoors are typically treated with these stabilizers. Ozone and acid rain, various atmospheric pollutants, can damage building materials. Ozone and other air pollutants damage materials, including rubber, nylon, dyes polyster, and certain paints, many synthetic materials.[Wilson 2007] Heat, cold, wind, snow, hail, ice, mechanical stress, acids, animals, plants, water and other liquids and micro-organisms are some of the external factors which can break down plastics. The type and the position of the plastic and the local climate determines the life-span of a plastic [Berge 2001].

It is difficult to anticipate the lifespan of most new materials like plastics. Although it is possible to create accelarated deterioration in laboratories, these are not the results of actual situation which is more complex. [Berge 2001] Causing embrittlement and a change in surface appearance short-wave solar radiation affects plastics negatively. In coastal and rural areas the risk is greatest. Using some additives incorparated into the plastic the effects can be reduced or increased. Adding fire retardants reduces resistance to degradition. Although, moisture in general has little effect but can reduce bond strength between glass fibre and polyester resin. Depending on the control exercised in manufacture greatly, the extend of any weakening of bond strength can be controled also. In general, contact with other building materials do not harm plastics, though the use of oil base jointing compounds cause cracking of polyethylene cold-water cisterns [Ransom, 1987].

PVC and polycarbonates have high thermal expansion and varieties of polyethylene have even greater thermal movement. Down pipes can cause joint failure and leakage, when the movement of PVC gutters, unless properly allowed for. Under continued, loads plastics creep when stresses are high, as in filled cold-water cisterns, special precautions are needed. [Ransom, 1987] It is also difficult to make a picture, as the plastics are often full of additives. Although PVC is known as a plastic with a very good durability, it has been known to undergo very rapid breakdown. Sometimes addiditives can be harmful, just the opposite of the expectations. One of the examples is crumbling of 10-year-old plastic skirtings made of PVC, because of an added acrylonitrile butane styrene (ABS)-plastic which should have increased the strength and durability. All plastics oxidize easily. Another plastic polyethylene sheeting, had an effective lifespan of ten years and used as a moisture barrier until 1975. As the sheeting is usually in accessible within the fabric of a building and often supposed to prevent

condensation within the walls, this is extremely low. Some additives included polyethylene to make it more stable [Berge 2001].

When the material has to be replaced or the use that material had is brought to an end, durability ends. A durable material is useful for longer. Durability is an indicator which informs if a material maintains its original requirements over time. The material durability will increase, when the time and resources required to maintain it decrease. [Mora 2007] Sometimes 1 year is enough losing functionality. Ethylene proppylene rubber (EPDM) is used as sealing strips between the elements in prefabricated building of timber and concrete. According to researches certain makes have lost elasticity after only one year and causing the joints open and the material does not function. As many of the plastic products currently on the market have been around for less than 15 years, there is very little feedback on their life span. Altough some of the products have been on the market, for a longer period, todays' components are very different from those that were used in products of 20 years ago, as it is well known by the polymer technicians. It is difficult to find examples giving a picture of the lifespan of the plastics products made today, as the design of products has changed so much recently [Berge 2001].

5 CONCLUSION

In construction industry, polymer based building materials have a rapid development and have been used widely throughout 1990s. Especially having different kinds and offering different types of design enabled them gaining popularity among architects. Polymer based building materials, especially plastics, are man-made, therefore there is no limit for the charasteristics and development will continue. New products with improved properties can be manufactured. This continuous development is the main difference between polymer based building materials and traditional materials. Additives help improving charasteristics against resistance to fire, UV ray and other disadvantages. Especially as an element of composite material specific performance charasteristics can be improved. The combination of distinctly different components of composites can make new high-strength, lightweight materials with corrosion resistance, long-term durability, low maintenance requirements, design flexibility, good vibrational damping and resistance to both fatigue and temperature extremes. The performance capabilities of the composites can be developed and high-performance composites can be manufactured. This means, quality of polymer based building materials can be developed also. Every material have some specific characters but a general definition of quality for polymer based building materials can be written as:
"A polymer based building material should be resistant to fire, UV ray, water and some chemicals, corrosion, moisture, thermal and mechanical stress, ozone and other air pollutants; should have good water and vapour proofing, high thermal insulation properties, and high strength and should be load bearing, lightweighted, appropriate for outdoor environment and lower in cost."

The characteristic of a building material being durable affects the level of quality or on the other hand improving the level of quality of a building material can affect the material being more durable. As quality enables to perform a stated task or to fulfill a given need satisfactorily for an accepted period of time, quality is improving the characteristics of a building material. Improving characteristics can also affect the material being more durable. Being a wall covering more durable it is needed to have an average compressive strength, a negligible level of moisture content, resistant to thermal stress, ultraviolet light and high wind pressure and it is also preferred to be sustainable. Improving a material having more compressive strength or decreasing the level of moisture, affects its quality level positively also. As the level of quality is increasing, the material can be more durable also. Polyvinyl chloride (PVC) or vinyl is perhaps the most versatile of all plastics. In construction vinyl is used as flooring, siding, piping and single-ply membrane roofing. Vinyl is generally self-extinguishing and resists weathering, oils, greases, acids, fungus and moisture and and abrasion-resistant depending on the type. One of the vinyl types used in building commonly is siding. There is little that challenges vinyl's versatility, durability and possible textures, colors and shapes. Vinyl siding requires little

maintenance, remaining attractive for years. These are the characteristics of vinyl siding and they can be listed as the quality criteria, also. Being recycling can be added as a quality criterion that nearly all waste of vinyl is recycled. [Knowles 2003] As a durable material lasts a long time and provides a long period of time to amortize the environmental and economic costs that were incurred in building it, durable materials and materials will not need to be replaced or repaired as frequently. So, the raw materials, energy and environmental impacts invested in them can be spread out over time. The longer-lasting building's higher economic and environmental costs can usually be justified by its durability.

Another building material is spray polyurethane foam (SPF) which is one of the fastest growing polymers in construction and can be used for specific purposes including roofing insulation, wall insulation, air barrier systems, and below-grade foundation insulation and below slap-on-grade. According to performance studies and research suggest SPF roofing systems can last 30 or more years. They require low maintenance, resist high wind blow-off, add structural strength and minimize moisture damage within the building envelope which are among the quality criteria. [Knowles 2003] Characteristics of the material can be developed also by using closed-cell formulations or open-cell formulations which is also enables developing the charasteristics of the material. Developing charasteristics of a material affects quality level positively, also, which will affect durability positively. Closed-cell formulations typically range in density from 27 kg/m3 to 51 kg/m3, while compressive strength ranges from 103 kPa to 345 kPa. The density and composition of closed-cell foams help the building gaining more structural integrity. When closed-cell MD-SPF is sprayed in place, makes the applied place seamless and 100-percent fully adhered. This means, SPF roofing limits moisture intrusion because of its 90-percent closed-cell properties. Damage to the system typically does not cause leaks into the building and moisture intrusion is isolated to the areas of damaged foam cells. SPF roofing system has exceptional wind uplift resistance. According to the researches SPF roofs applied over a built-up roof and metal increased the wind uplift resistance of roof coverings. The tests showed similar results for concrete, metal and wood. It requires no fasteners or adhesives, and may not shrink or sag over time, making it ideal for use in vertical wall and below-grade exterior applications. [Harris 2004] [Knowles 2003] Having needed characteristics of a building envelope also refers to the building material having needed quality level which means also affecting durability positively. According to the researches existing performance attributes of SPF has an average compressive strength and core density, offers a very high wind uplift resistance rating and average moisture content was negligible. SPF air barriers offer long-term durability greater than or equal to the building's life span which means the developed charasteristic of the material that affected quality positively, also.

As the type and the place where the material is used changes, needed quality criteria differs. The quality of a building material is the totality of its attributes. When there are any materials with less quality, it is important to be easily replaced with the more durable materials. A different quality definition is needed for every product which can be defined again through the view of durability. For instance the definition of quality for PVC can be written as: "A PVC building material should be resistant to water, some chemicals, tearing, thermal stability and moisture, should have high strength and low cost." When produced as a foam, PVC should have high thermal insulation properties and good water, moisture and vapour proofing properties. The more efficient use of building materials mainly tendencies like the improvement of the quality of the materials, affects improvement of durability, also. Having needed characteristics of a building envelope also refers to the building material having needed quality criteria. It means; if there is a stable interaction between heat, air and moisture transports, the building material will have needed characteristics which also show the level of quality. It affects also the durability. The durability of a material in a building envelope not only depends on the quality level of the building material but also the outdoor and indoor climate, type of construction and conditions of service, also.

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