SUSTAINABLE MEDITERRANEAN ARCHITECTURE WITH ALUMINIUM FACADES

TECHNICAL BRIEF

BUILDINGS, ENERGY & ENVIRONMENT

At the dawn of the new millennium, energy availability and environmental concerns are attracting even more attention and pose new challenges. Energy has long been recognised as a key factor for competitiveness and economic development, while environmental concerns have attracted a lot of attention in recent years, in view of the greenhouse phenomenon and possible global climate changes.

Energy consumption in buildings represents today about 35-40% of the final energy produced in the member states of the European Union (EU), and contributes about 40-45% of the carbon dioxide (CO_2) emissions released in the atmosphere. According to international statistics:

- 75% of the world's energy resources are consumed by the built environment, with its complex matrix of buildings, activities and transportation.
- 36-45% of a nation's primary energy consumption is used in buildings.
- 40% of raw materials (by weight) are used in building construction through-out the world, each year.
- 20-26% of landfill waste comes from building construction, renovation or demolition.

Heating, ventilating and air conditioning (**HVAC**) systems can be used for year-round indoor environmental control of temperature, humidity, and air quality, in buildings. However, they consume valuable energy resources, like fossil fuels for heating, or electrical energy for the operation of HVAC equipment. The shortage of conventional energy sources, their environmental impact, and escalating energy prices, have caused re-examination of the general building design practices and the use of HVAC systems.

The **energy crisis** in the mid-1970s shifted concern to improved building standards for reducing energy consumption, for example regulations for higher building thermal insulation to control heat losses and gains, increased equipment efficiency etc. In recent years, the 1997 **Kyoto Protocol** on **Climate Change**, for the abatement of CO_2 and other greenhouse gas emissions, boosted the importance of the environment dimension and sustainable development through out the world.

Sustainable architecture characterises the design of buildings that offer comfortable and safe indoor spaces for the occupants, while respecting the environment by minimising the use of natural resources and exploiting good life cycle economics. The generic term “bioclimatic” is also included in “sustainable or ecological architecture” and mainly refers to passive or hybrid (low-energy) design principles.

The use of **non-toxic** and **recyclable building materials** is a primary target for sustainable building. The use of materials that may cause direct or indirect hazardous emissions during their production or disposal phase should be avoided. **The use of safe materials, with a “closed life cycle” that allow reuse or recycling, must be encouraged** since they minimise the environmental impact either during production or during building renovation or demolition.

The choice of materials with **low embodied energy** (that is the energy required for their production) is vital. However, the material’s potential for reuse and recycling is more important, because its original embodied energy is reduced (depending on the energy cost for recycling).

One should try to combine the various issues of sustainability, durability and longevity, with local characteristics and conditions, while making the appropriate building material selection, taking into account their impact on the building’s energy performance and the environment. The challenge is finding the balance between environmental considerations and **economic constraints**.

Life Cycle Analysis (LCA) is considered as the most effective tool for cost and environmental impact benchmarking between various materials and designs, carried over the total life of the building (usually considered to be 50 years). This way it is possible to assess a possible investment, taking into account the operational and maintenance costs over the lifetime of a building.

The **building envelope** determines the physical processes taking place between outdoor environment and indoor spaces and plays a dominant role on the overall energy performance of a building. The objective is to always limit thermal losses during winter and thermal gains during summer. Proper thermal insulation can reduce the heat conducted through the building materials. The level of thermal insulation in buildings is determined by national codes and is mandatory in most countries.

The use of building designs, opaque and transparent elements or insulating materials that have been used and proven successful in different countries are not necessarily adaptable to other countries. Actually, the replication of specific building designs and use of materials, successful for cold climates, can prove disastrous in warm climates.

Modern buildings are designed to provide an optimum indoor environment depending on their function (working, leisure etc.). This way, occupants can optimise their productivity and fully utilise their human resources, perform in and enjoy an environment suitable for their activity. The **indoor environment** must provide proper **thermal**, **visual** and **acoustical comfort** conditions, and

air quality for the given use and function of the space. This demands a delicate balance of various parameters in order to reach the desirable conditions, usually referred to as **Indoor Environmental Quality** (**IEQ**).

Energy consumption depends primarily on the function of the building (i.e. commercial, office, hospital, school etc), type of construction and building envelope (material, insulation), controls and operating hours of mechanical systems, user behaviour, operating hours, type of HVAC system, and the type of fuel used. Building energy consumption is expressed in energy per unit floor area (kWh/m^2) or per unit volume (kWh/m^3) for large volume buildings, or per bed or per occupancy for specific functions of buildings, like hospitals and hotels. Depending on the building's function and HVAC installations, annual total energy consumption in European buildings can range between 80-450 kWh/m^2.

Energy conservation strategies need to address specific problems that depend on the requirements introduced by the specific characteristics of the building. Some of these problems are unique and are associated to the specific function of the building (i.e. specific indoor conditions, internal gains), while others are similar to all buildings (i.e. heat gain prevention through the building envelope during summer or heat losses during winter).

To improve indoor thermal conditions in buildings, one has to either invest a great amount of financial resources for the purchase, installation, maintenance and operating costs of conventional systems, or alternatively to reduce energy related costs, while maintaining suitable indoor conditions. The cost for heating, cooling, ventilating and lighting, can be very high, especially if there are faults in the design and operation of the building and its various facilities. Considering the fact that operational and maintenance expenses will grow with time and that problems usually get worse unless some actions are taken, it makes good sense to place an emphasis on energy conservation. In fact, **energy saving is really money saving**, that can add up over the years. The money saved can then be invested to cover other needs.

Energy conservation has become an important parameter and, in some countries, a code-mandated requirement. The main objective is to **achieve indoors environmental quality, while balancing the requirements for energy efficiency and overall energy conservation, in an environmentally acceptable manner**.

Building retrofit or renovation costs are much lower than the costs for building demolition and the construction of a new building. **Energy conservation in existing buildings is a priority**, given that the lifetime of buildings is usually more than 50 years and the existing stock of buildings is much greater than new construction. **Energy conservation measures** for new and existing buildings are already in process within several Member States of the European Union, in accordance to the new Directives by the European Commission on "Energy Conservation in Buildings".

Energy conservation for **heating** and the reduction of heat losses are mainly governed by thermal insulation of the building envelope. **Thermal insulation** materials have improved significantly over the past decades in terms of quality and thermal properties of materials, safety and functionality. The current average heat losses of new European buildings are about half of what it used to be for the pre-1945 building stock. Nevertheless, the majority of existing buildings are poorly insulated, since in most countries national thermal insulation regulations have been enforced during the last decades. For example, in Greece, where the national Thermal Insulation Code became effective in 1981, only 5% of the existing residential building stock is insulated.

Heat losses through the **building envelope** are responsible for about 10-25% of the total energy consumed in buildings, depending on outdoor weather conditions and building materials. Consequently, a well insulated building envelope can significantly reduce thermal losses in winter and heat gains in summer, thus reducing energy consumption and operating costs, and improving the indoor thermal conditions. The addition of an external cladding façade, at a proper distance from the main building "body", on existing and new buildings, creates an air gap that acts as a thermal buffer zone, thus reducing heat losses in winter and heat gains in summer. Thermal insulation materials should be added on the building "body", for additional energy savings.

Energy conservation for **cooling** of buildings is of **primary concern in the Mediterranean countries**. During the past decades, the use of mechanical air conditioners (A/C) in southern European countries has increased dramatically. This is primarily due to an increase of the living standards and the cost reduction of A/C units. There is a clear trend of increasing sales with gross national product (GNP) in EU member states. In Greece, the sales of A/C units showed an unprecedented increase during the late 1980s due to a series of heat waves over a period of three years. These events resulted to an unprecedented increase by 900% during this period. The impact on the electric energy consumption has been alarming. Peak electric energy loads occurred in Greece, for the first time, during summer. Similar trends have also been observed in most southern regions in Europe, the Middle East, the United States and Japan.

Solar control (**shading**) is the primary design measure for heat gain protection of indoors building spaces. The use of various shading devices in attenuating the incident solar radiation can significantly reduce the cooling load and improve the indoor thermal and visual comfort conditions. External shading is overall more effective because the main amount of incident solar radiation is intercepted outside the building and it can be dissipated away from internal spaces.

ALUMINIUM AS A BUILDING MATERIAL

During the past 30 years, the use of Aluminium for building applications has shown continuous and consistent growth. This is due to a number of key

performance advantages as a result of the following **material's characteristics**:

- Aluminium is non-toxic, non-magnetic, incombustible with no risk of sparking, thus inherently safe and healthy material.
- Aluminium has a long service life and requires limited, if any, maintenance, over the entire building life. High durability and strength are achieved by alloying the aluminium.
- Aluminium has a low specific weight. For example, its specific weight is only one third to that of steel. In addition, its high strength-to-weight ratio allows architects to minimise the load on the supporting structure.
- Aluminium is a good heat conductor. It can easily dissipate heat and it is thus considered a "cool" material. This is a positive feature in terms of alleviating the problems related to heat island effects from building materials.
- Aluminium, bare material or specially coated, exhibits high reflectivity versus low emissivity, both very important to solar radiation control.
- Aluminium offers considerable design flexibility. It can be rolled, extruded and cast to various shapes, it can be formed, sawed, drilled, bent and welded in the workshop or at the construction site.
- Aluminium can be anodised or coated with different colours. This way, it can meet different aesthetics and decorative needs, while at the same time enhancing its natural durability and corrosion resistance, and providing an easy-to-clean surface.
- Aluminium has a high intrinsic value and low recycling cost, thus reducing the costs of material dismantling during renovation or the cost of demolition at the end of the building life.

The main **environmental advantages** from the use of aluminium in the building sector, are based on the following facts:

- Aluminium can be recycled, time and time again, resulting to significant savings in energy and natural resources, without any downgrading of its properties. The required energy for recycling is only 5% of the energy used for its primary production with electrolysis. About 40% of all the aluminium used today, is recycled metal.
- Aluminium is a light material, and as a result the overall use of raw materials is low, minimising energy, transport and application costs.
- Aluminium can improve the building's energy performance with higher overall quality and economy of the building management.
- Aluminium can be reused or recycled, thus reducing the amount of building materials waste and landfill use.

CLADDING FACADES & SOLAR CONTROL ELEMENTS

Aluminium can be used for wall claddings and solar control systems. **Cladding elements** are panels formed either by specially coated 2-3 mm thick aluminium sheet (**EVAL ENF®**) or aluminium composite materials (ACM) that is a 4 mm sandwich composed of a 3 mm thick, non-toxic polyethylene core bonded between 0.5 mm coated aluminium facing and backing sheets (**ETEM ETALBOND®**).

Aluminium **cladding facades** can be used to renovate the external envelope of existing buildings and also for new buildings, providing an easily applicable and aesthetically pleasant material. Curved, flat and multiplanar surfaces, with various surface colours can meet any architectural demand. In some cases, aluminium can also be used as **roofing material**, especially for large volume, one-storey commercial buildings.

Aluminium **cladding facades** act as radiant thermal shields for the building "body". **In summer**, they reduce solar radiation absorbed by opaque elements. **In winter**, they provide a thermal buffer and wind screen, thus minimising thermal losses from opaque elements. **Year round**, it will reduce sound transmission through the building envelope and protect building materials from rainwater, environmental pollution and heat stress due to diurnal and seasonal temperature variation.

Aluminium cladding material can withstand natural forces, such as wind pressure, earthquakes (elastic character), and gravity (own weight), the effect of solar radiation (chemical deterioration produced by UV radiation), and thermal expansion / contraction due to diurnal and seasonal temperature variations.

Bare, coated or even perforated aluminium is also used for **solar control systems**. **External shading** of transparent surfaces is a priority, while shading of opaque surfaces can result to additional energy savings for air conditioned buildings and improved thermal comfort conditions.

External **shading devices** can be added components to the building for the purpose of solar control or integrated to the building envelope, as part of the overall building architecture. The **fixed types** are typically variations of two main solar control devices, namely: horizontal **overhangs** and vertical **side fins**, with different relative dimensions and geometry. Properly designed and sized, fixed external shading devices are effective during summer, while allowing the desirable solar gains during winter. The **movable types** are more flexible, since they can be adjusted and operated either manually or automatically. Typically the movable elements include various types and shapes of **awnings**, **roller shades**, adjustable **louvers** and **rotating fins**.

Aluminium facades and solar control elements are:

Aesthetically appealing

- Aluminium and composite materials can be easily transformed to flat, curved or angled surfaces, in line with contemporary architecture design practices. Aluminium panels can be placed on facades, with horizontal or vertical patterns, at designer-selected gap widths between elements. Aluminium horizontal overhangs, side fins or with any other geometry, can be used as solar control architectural elements.

- Aluminium can be made available in a wide range of different colours. State of the art coating technology provides a wide choice of high quality and long-life coatings. Especially for the Mediterranean climate, liquid polivinylidene fluoride (PVDF) coatings offer extreme durability against ultra violet radiation.

Physically advantageous

- Aluminium is a light material. Given the low specific gravity of aluminium (2,7 gr*/cm^3), one square meter of a 2mm thickness flat aluminium panel weighs only 5,4 kg. Aluminium composite materials have similar properties.
- Aluminium has an excellent strength-to-weight ratio providing strong cladding units and solar control elements.
- Aluminium has a high elasticity that makes it safer for regions with high earthquake activity.
- Aluminium has an outstanding corrosion resistance, due to the use of magnesium-alloyed aluminium, thus making the material practically maintenance free.
- Aluminium has attractive optical and thermal properties. Bare surface aluminium or coated with proper light colours, has a high reflectivity to radiant energy (visible light, heat radiation and electromagnetic waves) together with low emissivity, compared to other competing metal materials.

Easily designed and formed

- Aluminium cladding elements are fixed on a metallic supporting frame, preferably aluminium made, which is secured on the building's load bearing structure. Thermal bridging can be minimised or eliminated. The mode and fixing system for the façade elements can be selected from the following options:
  1. Cassettes, suspended from the supporting structure.
  2. Riveted or bolted sheets.
  3. Stud-welded sheets on their back (invisible bolts).
  4. Elastically bonded sheet elements on the supporting frame, with special adhesives.
- Aluminium panels can be easily formed and assembled. They have precision fit, facilitated by a consistent parametric design of the cladding system.
- Aluminium panels can be easily replaced, if damaged.
- Aluminium cladding elements can be easily engineered to provide robustness and stiffness of façade elements.

Aluminium Facades and Energy Conservation

The use of aluminium cladding on buildings can provide significant energy savings all-year round. For an non-insulated building, adding a proper insulation layer on the building "body" and an aluminium cladding at a proper distance, can reduce heating loads by up to 30% and cooling loads by up to 50%. The use of external solar shading is a prerequisite.

The concepts behind energy conservation are relatively simple. Success or failure though, is sometimes very close to each other. For that reason it is critical to realise that arriving at practical designs requires careful analysis, some level of experience and a sophisticated integration of various materials, technologies and techniques. Account for the constraints, specific needs, characteristics and available opportunities of every project, through a well defined strategy and integration of local traditions and conditions.

Aluminium as a metal or building element, conforms to all sustainability prerequisites. When properly designed and integrated in the building envelope, it can result to significant energy savings for buildings. The special physical attributes of high reflectivity and low emissivity can reveal the use of **Aluminium as a practical solution for Mediterranean buildings**.

The Greek Aluminium Rolling Company **ELVAL S.A.** and the Greek Aluminium Extrusion Company **ETEM S.A.**, invite students and architects to participate in an international competition for "**Sustainable Mediterranean Architecture with Aluminium Facades**". Held under the auspices of the International Union of Architects (UIA), the competition is supported by the Hellenic Institute of Architecture and the Greek Aluminium Association. The competition is open to **concepts or ideas** by Students from Schools of Architecture, Technical Universities and Polytechnics as well as Professional Architects from countries around the **Mediterranean Basin**.

The aims of the competition are:

- To raise awareness of environmental issues among students and architects;
- To disseminate the facts on Aluminium and its contribution to sustainability;
- To promote new ideas for low-energy buildings using Aluminium facades;
- To stimulate the exchange of best practice on the use of Aluminium as a building material around the Mediterranean.