

The historical development of thermal insulation materials

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Abstract

The history of thermal insulation materials is not as long as that of other materials, but the necessity of insulation is as old as building activity. Prehistoric people built shelters to protect themselves from the elements, originally using organic materials and later more durable substitutes.

However people used not only materials that were found in nature, but discovered others which were suitable for insulating. Processing organic materials produced the first insulated panels in the 19th century: meanwhile an increasing range of artificial materials were developed (rock wool, fibreglass, foam glass, hollow bricks, expanded perlite).

The appearance of plastic foams caused a huge revolution. Although plastic production was well-known in the 19th century, the first plastic foam was not produced until 1941.

Nowadays the most popular insulation materials are plastic foams and mineral wool with only a small amount of natural materials being produced. The overall growth of these products has been substantial due to a wide range of reasons.

Keywords

history · development · thermal insulation material

1 Introduction

The history of thermal insulation is not as long as that of other building constructions. Long ago thermal insulation did not form a separate layer in building construction because there was no need to build in extra materials to assure the insulating function.

The process of building activity appeared when prehistoric human beings first created shelters themselves. The main reason for this activity was protection against wild animals and the elements (cold winters, hot summers), i.e. insulation from the surroundings.

Accordingly we can reasonably assume that one of the most important requirements for building construction is the necessity of adequate thermal insulation which is as old as building activity itself and has existed since prehistoric times.

2 The early history of thermal insulation

The first prehistoric peoples built temporary dwellings from same materials that they used for clothing. The most common materials were animal skins, fur, wool and plant related products like reed, flax or straw, but their lifespan was limited. Later because of the settled lifestyle and the development of agriculture they needed more durable materials for housing, like stone, wood and earth.

Both earth-sheltered houses and cave dwellings were built at the same time and it appears they were very popular because of their inherent benefits. Their implementation was cheap and an earth covering assured excellent protection against wild animals, fire and during periods of fighting. In addition earth houses use soil as a magnificent insulating blanket, as due to the high density of earth, the inside temperature changes very slowly. This phenomenon is called thermal lag which is why earth covering keeps the interior warm in winter and cool in summer.

The houses in the Neolithic village of Skara Brae (Orkney Island, Scotland) are the oldest known – nearly 5.000 years old – earth-sheltered, green roofed dwellings in the world (Fig. 1) but we can come across similar buildings in cold climatic areas like Scandinavia, Iceland, Russia, Greenland and Alaska.

At the end of the 19th century the techniques of planning and

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Fig. 1. The Neolithic village of Skara Brae (Orkney Island, Scotland)

construction had developed and changed dramatically over a relatively short period. New building materials emerged (cast-iron, glass structures, concrete, steel) and structural systems were planned not in empirical ways but on calculative methods [6, 7].

At first, the main problem was caused by the unusual thermal expansion of these new materials. To avoid the cracks and resulting damage it became obvious, that these structures needed extra thermal protection [6, 7].

Furthermore the thermal insulation capacity of the slight cast-iron, concrete and steel constructions was much lower than a thick wall made of adobe or bricks resulting in greater heat loss and higher heating demands. By turn of the 20th century, it was clear that flat roofs made of reinforced concrete, and the light frame structures made of steel and wood also needed extra thermal protection.

Rising energy consumption and the relatively high costs of fossil fuels (coal, crude oil) during the worldwide economic crisis (Long Depression, 1873-1896) forced thermal power plants to reduce the heat losses from steam engines, heating equipment, chimneys and also building structures around them [15]. This and light frame construction were some of the reasons why industrial architecture started to utilize thermal insulation materials.

A focus of the developing technologies and their innovations was to improve human comfort in buildings. It was evident that the task soon became how to keep the heat in, with the role of thermal insulation becoming significant in residential buildings [6, 7]. Heating and ventilation equipment showed extraordinary development in the 1880s and the calibration of them became necessary. The calculation of heat loss and heat gain of buildings became the key problem for building mechanical engineers with the first theories on thermal insulation and building physics appearing at the same time [15].

From this time people started to use thermal insulation materials. At first they processed materials that were found in nature, but later other specific artificial materials were discovered that were suitable for thermal insulation.

3 Natural materials

Vegetable fibres have always been widely available. For thousands of years, native inhabitants of tropical areas built their lodges from dried eelgrass or reed. In cold climates reed and long-stemmed wheat straw was used particularly for thatching roofs. In the 12th and 13th centuries northern Europeans were building thatched houses with 60-80cm thick straw roof construction, and walls were often built of clay and straw. The dry, hollow fibre of straw and reed provided an excellent level of thermal resistance, so thatched houses quickly spread especially in the northern parts of Europe and America [3].

Processing these organic materials people produced the first insulated panels in the late 19th century (reed, cork, flax panels). They were cheap, however, but the main problem was their good hygroscopic ability, resulting in the need for additional damp-courses [6, 7].

Reed panels were first used in the 19th century as thermal insulation mainly in ancillary buildings. They were popular because they were impervious to decay but they had poor hygroscopic ability. At the beginning of the 20th century reed panels appeared with bituminous coatings but they did not spread because of their flammability and unreliable quality [6, 7].

In 1920 the American Celotex Company introduced insulating panels made of bagasse (a waste by-product of sugar manufacturing). It was used as thermal insulation in home construction and in the manufacture of refrigerated railroad cars. Owing to their flammability, later one or both of the sides were coated with asbestos cement. The first attempts to produce *flax panels* for roof insulation were made in the USA and eventually around 1910 the first products (Flaxlinium, Fibroleft) were put on the market [3, 6, 7, 14].

Indigenous people by the Caribbean Sea built their huts from *dried eelgrass* (*Zostera marina*) which had as good insulating qualities as reed or straw. Reviving this technology in 1893, the American industrialist, Samuel Cabot (1850-1906) developed a new insulating blanket called Cabot-Quilt. This product consisted of dried eelgrass which was sandwiched between two layers of craft paper or asbestos. It was advertised as impervious to decay, fire and vermin. Cabot-Quilt was typically installed within walls and floors and the product remained on the market until the 1940s [3, 14].

Cork was firstly applied as insulation in the Mediterranean. The ancient Romans used it in shoes to keep their feet warm, but as we know from Caius Plinius Secundus the Elder (23 AD – 79 AD), the Romans used it for insulating roofs. In the Middle Ages monks in Spain and Portugal sheathed the inner side of the walls in their monasteries with cork. Some native tribes in North Africa also used a special mixture of clay and cork bark to construct the walls of their dwellings [3].

The first cork insulating panels were produced in the 1870s. People used them for sheathing the inner side of facade walls. Nevertheless, they had serious problems: beneath the panels

condensation developed and various kinds of parasites (fungus, insects) established inside. Cork panels were also difficult to plaster so they were rather hung with wallpaper. In the 1880s some products made from pulped cork, lime and clay appeared. They had lower insulating qualities, but they had a lower vapour resistance. These products were mainly used for pipe insulation [6, 7].

Straw bale construction was born with the first machine-manufactured modular bales: the first buildings made of straw bale were built in the 1880s in Nebraska (USA). Housing was an urgent necessity and among the sand hills the only available building material was straw. Settlers planned to build stone houses as soon as they had enough money so they left the façade wall unfinished. Later in order to create more familiar surroundings, the straw bale huts were plastered both inside and out. Straw bale construction is again seeing a significant revival in its use. It can be used as in-fill wall system in half-timbered houses, core insulation in multiple-layer wall structures or ceiling insulation in attic spaces [3, 10].

In the 1930s there were several attempts to manufacture structural insulated panels of *compressed straw*. This technology was patented by Theodor Dieden in Sweden in 1935. The method developed and in the late 1940s Torsten Mossesson started the production of compressed agricultural fibre under the name of Stramit. Since then this product has spread all around the world as core insulation in frame structures [9, 11].

In the early 20th century *wood shavings* and *sawdust* were very popular insulation products because their costs were very low and the raw material was readily available. These materials were often mixed with various chemicals to increase their resistance to water absorption, fire and mould [10, 11].

The history of *wood wool* insulation dates back to 1842 when Herr von Pannewich in Breslau (today Wrocław, Poland) produced bedspreads by processing pine needles. With the first shredding machines appearing in 1876, the mass production of wood wool became possible. Because of its good hygroscopic qualities, towels and nappies were also made of it.

Only in the early 20th century did the idea to make insulation panels from it arise. The first wood wool insulating product was made in 1908 by the Heraklith Company in Ferndorf (Austria) using magnesite and cement as an adhesive. Nevertheless the first products had several disadvantages (flammability, poor dimensional stability) however wood wool insulation soon spread worldwide. It was used together with a plasterboard covering as ceiling and wall insulation. Moreover it was good for stay-in-place formwork in concrete structures [6, 7, 11].

Cellulose insulations appeared in the 1920s in Scandinavia and they were prepared from forestry by-products. Originally they were employed as core insulation in traditional half-timbered houses and sometimes as insulation for attic spaces. Cellulose insulation is applied widely nowadays because of its rapid implementation [10, 11].

Materials of animal origin are the most ancient thermal in-

sulation materials. Prehistoric humans made warm clothes and shoes from animal skins, fur and wool to protect them against the cold winter. These materials were suitable for insulating their huts and tents but in the 20th century insulating blankets made of sheep's wool appeared on the market. They are currently utilized because of their ecological and economic benefits.

Dried manure had acceptable insulation properties and it was widely used by elementary architecture. Even to the present day we come across it in some underdeveloped areas [10, 11].

4 Artificial materials

Besides the natural products, several artificial materials were also developed during the industrial revolution. They had many advantages over the natural materials (durability, fire and water resistance) gradually taking over by the first third of the 20th century.

4.1 Mineral wool products

Natural *asbestos* is a fibrous mineral and its benefits (fire resistance, high tensile strength) were already identified in ancient times. Archaeologists have found 3000 year-old log homes in Finland, in which asbestos was used for chinking. The ancient Egyptians also used asbestos to strengthen their clothes, but only the ancient Greeks used it extensively. To take advantage of its flame-resistance, asbestos was used in spaces that were exposed to intense heat.

The ancient Romans fabricated clothes, towels, tablecloths and napkins of asbestos. Because of their flame-resistance they were easy to clean by throwing them into a fire, where the dirt and contaminants were burnt out.

Asbestos became a popular insulating material during the industrial revolution. The manufacturing industry used it for insulating pipes, steam engines, boilers and chimneys. Later it was used in the vehicle industry (brakes, clutches) and in the manufacture of household devices (refrigerators, irons, hairdryers).

The harmful effects of asbestos were known even in ancient times but unfortunately these were forgotten until the beginning of the 20th century. In 1897 an Austrian doctor documented the first ailment caused directly by asbestos. The first proved asbestos-related death occurred in 1906. As the dangers of asbestos became apparent, the use of asbestos was forbidden in many countries of the world [3].

Natural mineral wool is formed from effusive rocks when the escaping steam turns the molten lava into a fluffy fibre. Native inhabitants living near volcanoes (Hawaiian Islands) used this material to blanket their huts [3].

The first commercial mineral wool insulation was invented in Wales by Edward Perry in 1840. He insulated pipes and machines to reduce their heat loss and reduce the risk of accidents, but the production was abandoned because of its harmful effects on workers.

The first manufacture of *slag wool* began in 1885 in Manchester (United Kingdom). *Rock wool* was first prepared from limestone by the American chemical engineer, Charles Corydon Hall in 1897. The commercial production of rock wool started in Alexandria (Indiana, USA) in his factory called the Crystal Chemical Works [3, 11]. It was a very popular in-fill insulation in light frame structures.

The raw material of rock wool (limestone, basalt) is melted in a gas-heated smelting furnace at a temperature of 1500-1600°C through which steam or air is blown. Then with a help of high speed spinning wheels fine and intertwined fibres are generated with a diameter of 6-10µm. During this action some binder material (phenol-formaldehyde resin, oil emulsion) is added.

The ancient Egyptians and Venetian glassmakers had already discovered that they could make threads from hot glass with which they decorated their vessels but the mass production of *fibreglass* was only made possible by the invention of fine set machines.

In 1893 Edward Drummond Libbey (1854-1925) experimented with glass fibres with the diameters as fine as silk fibres, with the first fibreglass insulation being introduced in 1938 by Russell Games Slayter (1896-1964), a researcher of the Owens-Corning Company [3, 11].

Fibreglass contains quartz sand, limestone, dolomite and 50-60% recycled glass: this is first melted at a temperature of 1400-1500°C. The molten glass is jetted through tiny heated holes into high-speed air streams. The results of this procedure are very thin and long fibres. Their surface is filmed with binder materials (phenol-formaldehyde resin) to form insulating blankets.

4.2 Foam glass [11, 13]

In the 1930s there were three similar patents to produce *foam glass*: The American Albert L. Kern patented a method in 1931 using silica with 20% combustible material (lignite, coal, wood) and foaming agents (hydrochloric acid, sodium hydroxide solution). He heated this mixture to 1500°C resulting in a porous product. The laboratory engineer (I. I. Kitaigorodsky) of the Mendeleev Institute of Moscow developed another method to create foamed glass in 1932. He took a mixture of finely powdered glass and calcium-carbonate (CaCO_3) as a foaming agent and heated it up to 850°C, then cooled it in steel moulds.

Another type of process was developed in 1934 using a mixture of finely powdered silica, borax and zinc oxide. Heating it up trapped gases given off, leaving a raft of bubbles with a cellular body. This technology was further developed by William O. Lytle, a laboratory technician of Pittsburgh Plate Glass & Corning Glass Works (Pennsylvania, USA). In 1940 he patented a procedure using additional foaming agents (air, water vapour) to create extra pores. This foam glass product was lightweight, rigid, fire, water, rodent and insect-resistant, so it was easy to introduce it as a new insulation material. The mass production of foam glass started in 1943 in Port Allegany (Pennsylvania, USA).

4.3 Bricklaying elements

In the 1870s and 1880s there were projects to lighten and to upgrade the thermal insulation qualities of *ceramic bricklaying elements*. The first attempt was Bischweiler's brick. This ceramic element consisted of two parts, a hollow ash-filled lower and a solid upper section. Unfortunately the insulating capacity of it was not as good as expected, moreover it had poor mechanical strength [6, 7].

The first unsuccessful attempts inspired manufacturers to come up with their own innovations, so at the very beginning of the 20th century, the first *hollow building bricks* appeared. The first products also had poor mechanical strength and insulating qualities but their quality progressively improved and they are now produced in huge quantities [6, 7].

At the same time porous bricks were also manufactured. They were baked together with coal-dust or tuff. These additives having burnt out in the fire left small pores in the bricks resulting in homogeneity and better mechanical quality. This technology uses sawdust or plastic granulate today. At the beginning of the 20th century there were also hollow bricks filled with diatomaceous earth [6, 7].

In 1918, the Swedish architect, Johan Axel Eriksson (1888-1961) commenced a research to create a new rot, mould and fire-proof building material: finally in 1923 he patented a method for creating *aerated autoclaved concrete* (AAC) joint blocks made from lime, metal powder and crumbled oil shale. In 1929 Karl August Carlén (1876-1960) the owner of the Yxhult Stenhuggeri AB (today Ytong AG) started the production of this new material under the name Ytong (Yxhult Angherdede Lättbetong) [11].

Today the technology uses ground calcined lime, gypsum and quartz sand, water and aluminium powder as a gas-forming agent. The lime reacts with the water, creating slaked lime (Ca(OH)_2): the aluminium powder then reacts with calcium hydroxide and with water, forming hydrogen that foams the mixture, creating internal pores with a diameter of 2mm.

After this procedure the blocks are placed into an autoclave chamber (10-12 hours, 8-12 bar, 170-190°C) to create solid blocks. Since then many other technologies have been developed to prepare porous, lightweight concrete joint blocks and they are manufactured worldwide.

4.4 Loose insulations

Slag was used first as insulation for flat roofed and slab structures in the 19th century. Because of its low price it was very attractive. However its main disadvantage was the extraordinarily heavy dead weight that was increased by the condensed water vapour accumulated in the structure owing to the good hygroscopic ability of dross. From the 1930s slag was only permitted in combination with adequate ventilation to ensure the removal of any water vapour [6, 7].

Perlite is actually a type of natural volcanic glass (riolite) with relatively high water content having various names until the of-

ficial name “perlite” was given to it in 1822.

Although there were experiments in 1929 in Japan with perlite, the real breakthrough came in the 1930s when expanded perlite was invented in 1938. L. Lee Boyer in his assay office in Superior (Arizona) wanted to fuse a mixture of silicates to create a new insulation material. One day he spread a sack of crumbled perlite into his furnace that was heated to 850-900°C and saw that suddenly the grains of perlite began to pop. Boyer examined the final product curiously and made a discovery. When this material is heated, the surface of the grains softens and in the pores the sealed water changes into steam that causes a 7-16 fold increase in volume of the perlite [1].

The cellular structure of the expanded perlite results in resistance to the conduction of heat, moreover it is fireproof and extremely lightweight. As a result by the 1950s it had spread worldwide. Expanded perlite could be used as loose insulation in slab structures and also as an aggregate in mortars and lightweight concrete [1].

The technology of manufacturing *expanded clay* was invented in 1917 by the owner of a brick factory, Stephen John Hayde in Kansas City (Missouri). Burning out the bricks he noticed abnormal expansion of some bricks made of a certain raw material. This observation gave him the idea for making expanded clay and in 1918 he patented his process [4].

He used crumbled shale that was heated up to 1000-1200°C in a rotary kiln. Because of the high temperature the surface of the grains softens and the sealed organic pieces are burnt. The arising gases cause a 4-5 fold increase of the grains size leaving pores inside that give valuable thermal insulating power to this product. These grains with the diameter of 4mm are used generally as an aggregate in lightweight concrete [4].

From the 1920s the technology of expanded clay spread in the USA, but it came to Europe only in the 1940s following the work of the Danish Oskar Olsen who patented a similar technology in 1919 [4].

5 Plastic foams [2]

The appearance of *plastic foams* (polystyrene, polyurethane) created a huge revolution in the market of insulation materials in the 1940s and 1950s. From this point on artificial insulation materials (plastic foams, mineral wool) overtook to force back the natural materials. After the oil crisis of the 1970s their spread accelerated and today artificial materials represent about 90-95% of the total thermal insulation material production.

There are three methods for producing plastics today (polymerisation, polycondensation and polyaddition) from which the first two were well known in the 19th century. Polymerisation in natural circumstances was first observed in 1838 by Henri Victor Regnault (1810-1878). The first human-made polymer was presented by the American chemist Charles Nelson Goodyear (1800-1860). In 1839 he tried to vulcanize rubber gum in a hot stove and discovered that it changed into a durable and flexible material.

Another technology for producing plastics – polycondensation – was invented by Johann Friedrich Wilhelm Adolf von Baeyer (1835-1917). In 1871 he prepared phenolphthalein (C₂₀H₁₄O₄) with the condensation of phthalic anhydride (C₈H₄O₃) and phenol (C₆H₅OH) under acidic conditions [2].

5.1 Polystyrene foam [2, 8, 11, 12]

Polystyrene had been known long before but it was not in use until the 20th century. Its original monomer was the natural styrene that was named after a genus of tropical and Mediterranean trees called *Styrax*.

In 1839 a pharmacist in Berlin, Eduard Simon distilled an oily, colourless, fragrant and refractive substance from *styrax* and named it styrene. A few days later Simon observed that this material had changed into a thick, jelly mass. He presumed that it happened as a result of oxidation so he named this compound styrene-oxide. In 1922 the German organic chemist Hermann Staudinger (1881-1965) realized that heating styrene up to a high temperature starts a chain reaction that produces macromolecules.

The monomer of polystyrene can be commercially manufactured from petroleum which is a mixture of around 500 various substances. Industrial oil extraction started in the 1850s but the first plastic made of petroleum – Bakelite – was created only in 1907 by Leo Hendrik Baekeland (1863-1944).

So it is no wonder that we had to wait until the 20th century for the invention of synthetic polystyrene. In 1929 in Ludwigshafen (Germany) the researcher of the IG Farbenindustrie AG (today Badische Anilin und Sodafabrik) Hermann Franz Mark (1895-1992) produced synthetic styrene with the catalytic dehydrogenation of ethyl-benzene at a temperature of 500-600°C. In 1930 two scientists from the company, Karl Wulff and Eugen Dörrer, carried out a successful polymerisation with styrene creating polystyrene. Thereafter the industrial production of polystyrene began and the utilization of it as plastic foam followed shortly after.

Polystyrene foam was first made in 1931 in the USA. The Swedish inventor Carl Georg Munters (1897-1989) cooperating with John Tandberg (1896-1968) patented the method for foaming polystyrene. Applying their technology the first polystyrene foam was produced in 1941 by Otis Ray McIntire (1918-1996), an engineer of the Dow Chemical Company. He heated the milk-white polystyrene granulate up to 200°C in an extruder using a chlorinated hydrocarbon (chloromethane) as a foaming agent. He led the polystyrene foam through a narrow aperture which resulted in extruded polystyrene (XPS) panels with a 98% closed cellular structure. The first polystyrene insulating product was put on the market by the company in 1943 under the name of Styrofoam®.

Another technology – the expanded polystyrene foam (EPS) – was invented in Germany by the engineers of IG Farbenindustrie AG in 1950. Using pentane as a foaming agent the polystyrene granulate is supplied with water vapour. As the temperature rises

the grains of the raw material grow soft and the effects of the pentane results in a 20-50-fold increase in the volume of the pearls. During this action small closed cells arise inside, as a result of which, the expanded polystyrene foam has excellent thermal insulating capacity creating an ideal building insulation material.

To create a useable and saleable product a technology for making blocks was needed. Researchers noticed that after the foaming procedure the surface of the cooled polystyrene pearls becomes solid, the foaming agent contracts, so air is able to infiltrate the cells. When the blocks are rested for a few days the water vapour added during the steaming evaporates. If these pearls are steamed again in a closed mould they form a regular block without a binding material. The first product made with the help of this technology was put on the market in 1951 under the name of Styropor®.

5.2 Polyurethane foam [8, 11]

To manufacture *polyurethane foam* (PUR), the invention of the third method of producing plastics was necessary. Polyaddition was invented accidentally in the United Kingdom in 1933 by laboratory engineers of the Imperial Chemical Industries (ICI), Reginald Gibson and Eric Fawcett.

They researched the chemical reactions of various organic compounds at high temperature and under high pressure. One day they reacted ethylene (C_2H_4) with benzaldehyde (C_6H_5CHO) in the expectation of creating a new kind of ketone. They left the reactor vessel switched on all night and in the morning they found a small amount of a white waxy solid that today is known as polyethylene.

Applying their technology in 1937 Otto Bayer (1902-1982) in Leverkusen (Germany) prepared polyurethane in the research laboratory of IG Farbenindustrie AG (today Bayer AG) with a reaction of glycol and polyisocyanate. During World War II polyurethane foam was applied as an aircraft coating but the final breakthrough came in the 1950s when the production of polyisocyanates became possible. The first commercial insulating panel made of polyurethane foam was produced in 1954. In those days these panels were poorly workable and they tended to distort, but the development of mounted polyurethane panels has made it possible to use them as a common building insulation material.

6 New thermal insulation materials after the 1950s

After the 1950s plenty of other new thermal insulation materials were introduced. Some of them were also plastic foams. Polyester foam (PES) and polyethylene foam (PE) were invented in the 1950s. Phenolic foam (PF) and formaldehyde foam (UF) appeared in the 1970s and melamine foam (MF) arrived in the 1990s[10].

Work to develop new thermal insulation materials continues, with the most successful products likely to be transparent

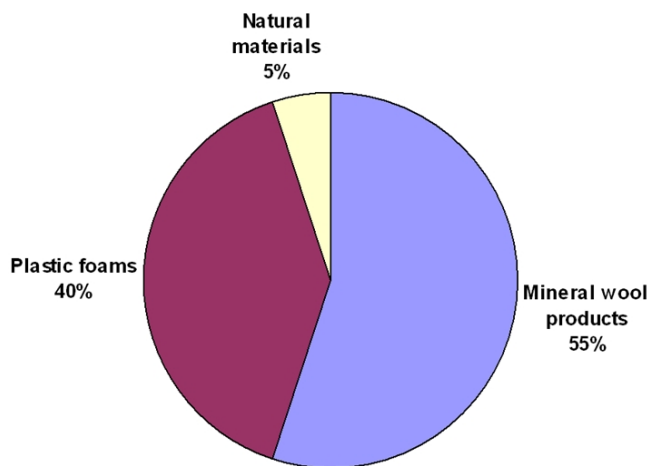


Fig. 2. The market of thermal insulation materials

thermal insulation, switchable thermal insulation, nanocellular foams and vacuum insulation panels (VIP).

7 Conclusions

Summarizing the development of thermal insulation materials we can separate five different periods of time. Each period started with a significant step in the historical development of humanity, science or industry. These were the main causes of change in the market of thermal insulation materials that resulted in the appearance of a new or disappearance of an old product (Table 2).

If we analyze the market for thermal insulation materials it is clear that the most popular products are the artificial materials. Mineral wool products represent about 50-55% and plastic foams about 40-45% of the total production.

It became clear in the last century that the amount of fossil fuels is finite and they will be exhausted within a relatively short time. In addition the serious issue of the 21st century, that of climate change and global warming results largely from the emissions of greenhouse gases (especially CO_2) from the use of fossil fuels.

Heating is around 70-80% of the total energy consumption of a normal family house. Heat loss can be reduced with the help of thermal insulation so the costs of heating and CO_2 emission can be reduced at the same time.

The production of artificial thermal insulation materials needs significant amounts of energy and further use of fossil fuels, therefore the demand for natural thermal insulation materials is on the rise. For example in Germany the production of them has grown from 1% to 6% in the last two decades (Table 2).

Their production requires much less energy so their spread should be substantial. Unfortunately this is not the case as people are wary of them. They have several disadvantages in relation to artificial materials (flammability, low durability, often poor dimensional stability, hazards associated with rodents, insects etc.) and their advantages (environmentally friendly, economical, inexpensive) are often relegated to the background.

Tab. 1. The historical development of thermal insulation materials

Period of time	causes of change	Changes	Insulation materials
2.5 mill - 7000BC	nomadic lifestyle	materials for clothing	animal skins, fur, wool
7000BC - 1870AD	settled lifestyle	durable materials vegetable fibres	earth, wood, bricks straw, eelgrass, reed
1870-1950	industrial revolution calculations about heat loss	first natural insulating products	reed, cork, wood wool and flax plates, cellulose insulation
		development of bricklaying elements	ash-filled bricks, hollow bricks, AAC
		first products of artificial insulation materials	asbestos, rock wool, fiberglass, foam glass, dross, expanded clay and perlite
1950 -2000	spread of plastics	spread of artificial materials apperance of plastis foams nearly disappearance of natural materials	polystyrene, polyurethane, polyester, polyethylene, phenolic, formaldehyde and melamin foam
	CO ₂ emission exhausting fossil fuels climate change global warming	revival of the natural materials	cellulose insulation, cork, straw bale, wood wool, sheep wool
2000 -		experiments with new materials	transparent thermal insulation, swichable thermal insulation, nanocellular insulation, vacuum insulation panels

Tab. 2. The market of thermal insulation materials in Germany in 1989-2004 [5]

Year	Mineral wool	EPS	XPS	PUR	Natural materials	Others
1989	59%	32%	3%	5%	1%	-
1994	60%	31%	4%	4%	1%	-
1999	58%	28%	4%	4%	5%	1%
2004	54%	28%	6%	6%	6%	1%

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