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IMPROVEMENT IN FRENCH INSULATION TECHNIQUES FOR OPAQUE PARTS OF THE ENVELOPE

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Improvement in French Insulation Techniques for opaque parts of the envelope

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INTRODUCTION

In the field of insulation techniques, technical advances are mainly due to an interactive approach resulting from three complementary factors :

- o National building standards and government supported incentive programmes which aim to increase the thermal efficiency of residential and commercial buildings.
- o Research and Development programmes set up by manufacturers in order to lead to new or improved insulation materials or components with increasing R-values.
- o New construction techniques used by designers and builders to reduce heat loss through building envelopes.

This paper gives a brief description of the consequences of the French thermal regulations on the efficiency of the building sheath, the most efficient insulation techniques used to meet standards and on going research on elaborate insulation products.

1. FRENCH THERMAL REGULATIONS CONCERNING BUILDING ENVELOPES

The efficiency of residential building envelopes against heat loss is characterized in the French thermal regulations by a GV-value expressed in W/°K.

The GV-value agregates :

- heat loss through walls, ceilings, roofs, floors, and windows in proportion to their U-values and surfaces.
- thermal bridges due to connections between external surfaces of the envelope (roof or floor and walls, wall and partition-walls, walls and windows).
- thermal loss due to ventilation and air infiltration.

As indicated on figure 1, GV-values for new buildings have been greatly reduced since 1974, due to increasingly severe standards because of oil prices and the high cost of energy.

The GV-value is 43 % lower for a 1984 electrically heated individual house than for a similar one built in 1974. The difference is important too between similar dwellings in apartment buildings respectively built in 1974 and 1989 (36 % for an electrically-heated dwelling and 32 % for a gas-heated one). To meet requirements, insulation materials and components used for walls, roofs, floors and windows have been strongly modified or totally re-designed during the last fifteen years.

2. CONSEQUENCES FOR WALLS, ROOFS AND FLOORS

2.1 Current building techniques in France

The most common building technique for walls is masonry of concrete blocks, bricks or heaped concrete. The thickness of walls ranges from 16 cm to 20 cm and they are insulated on site, mainly by means of interior insulation systems and less frequently by external insulation systems("mantel-wall" systems).

Manufactured concrete components with sandwich insulation are also often used in the commercial and apartment building sectors.
"Curtain-walls" (manufactured insulating panels) are frequentely used for commercial building facades.

Other techniques such as cellular concrete or insulating blocks are also present in the residential and commercial building sector. Attics are generally insulated using mineral wool rolls or blown wool.

Manufactured insulating roofs, which replace the framework and directly support the tiles, are also currently used.

Flat roofs are insulated above with rigid extruded polystyrene (XPS) or polyurethane foam (PUR) covered by a watertight layer.

Floors are usually made with prefabricated concrete components or by using heaped concrete.
About 18 million m^3 of insulation materials are used each year to insulate 150 to 180 million m^2 of new and existing buildings.

Figure 2 indicates the division in terms of buildings types, surfaces and insulating materials types.

Regarding the new building requirements, mineral wool and cellular plastics are the most appropriate products. Other materials such as vermiculite, cellulose, cellular glass, cork, expanded perlite, wood fibre are not often used for new building insulation. Glass or rock wool is used in the form of batts for walls, floors and flat roofs, and in the form of rolls and blowing wool for attics. Cellular plastics, such as expanded polystyrene (EPS), extruded polystyrene (XPS), polyurethane foam (PUR) are used for walls, roofs and flat roofs.

To meet the standards, professionals have successively used different methods.

2.2 Increase of insulation thickness

This is the easiest and most common way to meet standards, used by designers and constructors to improve the thermal efficiency of buildings without modifying well-known products and techniques, such as EPS-gypsum board panels for interior wall insulation, or mineral wool rolls for attics or cathedral ceilings. Nevertheless, the greater the thermal efficiency requirement is, the poorer the profitability of over-thickness becomes. A 100 % increase in the insulation thickness (R-1.5 to R-3 for walls or R-3 to R-6 for attics) only reduces the heat loss by 45 %. (see figure 3).

With current building techniques and for the 1989 new national residential building regulations (see figure 4) the total wall thickness can reach 34 cm for concrete blocks and 12 cm for the thickness of interior insulation. The loss of habitable area is consequently important : 5 to 10 m^2 for a 100 m^2 dwelling.

Increasing the thickness of insulating systems (for future thermal standards for instance) limit their applications for walls and floors. This solution is only available for attics but with poor profitability.

2.3 Substitution of insulation material

With high thermal requirements, it is profitable to replace the usual insulation materials by more elaborate ones, so as to reduce the total thickness and the loss of habitable area.

Interior insulation manufacturers or insulating roof manufacturers have developed such components with XPS or PUR (λ=0,029 W/m°K) to replace EPS (λ= 0,040 W/m°K). With this full 25 % improvement on λ-value, heat loss decreases by 25 % with the same thickness.

On one hand, these more efficient components are of interest to designers and builders because they can use well-known techniques for wall, roof and floor insulation. On the other hand, these techniques must compete with cheaper materials such as EPS or mineral wool.

2.4 Reduction of thermal bridges (see figure 5)

This method has been used for many years to design new systems with high efficiency and thermal homogeneity of the building envelope, such as external insulation systems or insulating block systems.

- External insulation systems

In just a decade, the market for façade insulation has greatly increased in France. From 1.500.000 m^2 in 1979, it reached over 7.000.000 m^2 in 1990. This market concerns about 50 manufacturers and 200 different systems. Three types of systems share the market :

- Facing on insulating materials

Insulation panels (usually made of expanded polystyrene) are glued onto facades, then covered with a reinforced facing. Two types of facing are used : either synthetic, resin-based or water-based (eg. cement or mortar). The first type (or thin facing) is composed of three layers : the undercoat (onto which the glass-fiber grid is applied), a primer coat and a finishing coat. The second type (or thick facing) is applied in one or two coats on a metal support bolted to the wall.
Facing on insulating materials represents 63 % of the market (about 56 % for resin-based facings and 7 % for water-based facings)

- Cladding panels in conjonction with thermal insulation

This system consists of an outer skin made of different materials (terra-cotta, slate, metal, resin, etc...) fixed by means of a framework. The insulating material is fixed against the facade. It is generally made of rock wool in semi-rigid panels. A ventilation space between the insulating material and the cladding panels ensures the evacuation of humidity and the preservation of the framework, generally made of wood. This technique requires several stages of assembly on site. Cladding represents 27 % of the market.

- Prefabricated cladding

This is a more recent technique. The first application dates from 1982, therefore the market share is still small (6 %). The cladding is made of prefabricated components consisting of a skin (metal, plastic, resin) in conjunction with an insulant (generally expanded polystyrene). The cladding is fixed to the facade mechanically in a single operation, thus allowing a reduction in installation time and cost. Prefabricated cladding is the most promising current innovation in facade insulation.

New buildings represent a small share of the external insulation market. 90 % of this market is made up of existing housing because in new buildings, external insulation is in competition with the apparently cheaper method of interior insulation. Despite this it seems highly likely that facade insulation will continue to develop, since the tightening up of insulation standards for new housing will almost certainly lead to the mandatory elimination of structural thermal bridges.

In order to increase the number of buildings concerned, 35 manufacturers, the Ademe and the CSTB are now acting together in the "Groupement des Industriels du Mur Manteau (G2M) (Mantel-wall manufacturers group) to promote external insulation techniques and to conduct investigations relative to :

- the reliability and durability of facade insulation systems,
- the reduction of the cost of these systems.

- Insulating blocks for masonry (see figure 6)

This title covers two different types of insulating block wall systems :

- expanded polystyrene block wall forming systems
- masonry blocks with an integrated polystyrene core.

About 50 different systems of insulating masonry blocks are available in France. They all appeared during the 80's to meet energy efficiency requirements of the 1982 and 1989 standards for new housing.

* The expanded polystyrene block walls are stacked dry. Cutouts for windows, doors and other openings are made in the polystyrene material using a saw. Horizontal and vertical rebar is inserted as the courses are laid. Concrete is then poured or pumped into horizontal and vertical cores. The complete wall consists of a concrete post and beam structure surrounded by expanded polystyrene.

  The interior surface is finished with glued plaster boards and the external surface is recovered with a reinforced, synthetic resin-based facing.

* Masonry blocks with an integrated polystyrene core are used like the current techniques of masonry but the work needs to be very well done on site to avoid prejudicial thermal gaps or thermal bridges.

  These blocks generally consist of two completely separate concrete faces which are interlocked with a continuous polystyrene foam insert. The concrete faces are made with conventional concrete but because there are no concrete webs extending through the block, the systems have high R-value. The mortar joints between the blocks are also thermally broken by foam insulation.

The U-values of walls built with these systems are good when compared to the French standards. They range from 0.3 $W/m^2{}^oK$ to 0.5 $W/m^2{}^oK$.
Three million m^2 of insulating blocks are used each year by builders for individual houses and small appartment or commercial buildings. (In comparison with 23 million m^2 of new walls to be insulated each year in France).

2.5 Improvement of the thermal conductivity of insulating materials

This move towards higher insulation is mainly due to the French procedure of labeling which came into effect in 1985, to justify the quality of insulating materials. Consequently it is now profitable for manufacturers to improve the thermal conductivity of their products in order to obtain the full effects of the "ACERMI certification" issued by approved public laboratories.

To greatly improve the efficiency of such materials, many physical parameters need to be studied and well modelised before modifying the manufacturing process :

- orientation and size of mineral fibers or cell foams
- density of the blowing gas
- amount of gas loss over time...

The physical limits for thermal conductivity are 0.024 W/m.°K for air-filled insulant (mineral wool, expanded polystyrene) and 0.015 W/m.°K for CFC 11 or 12 filled insulating materials (extruded polystyrene, polyurethane foam, phenolic foam) which are generally considered to be super-insulating materials.

The lower certified values of thermal conductivity of insulating materials available today on the French market are :

- semi-rigid glass wool panel : 0,030 W/m.°K
- rigid extruded polystyrene panel : 0,025 W/m.°K
- rigid phenolic foam panel : 0,021 W/m.°K
- rigid polyurethane foam panel : 0,020 W/m.°K

Research is also being carried out to improve the thermal conductivity of molded expanded polystyrene by modifying its manufacturing process without increasing the density of the material itself.

This on-going research could lead to a significant decrease in the high value (0,042 W/m.° K now) of this very widely used material.
Nevertheless all the improvements on CFC-foam insulation which were made between 1985 and 1990 have now in part been cancelled out by the CFC-ban.

It is expected that the use of substituants to CFC (R 123, R 141 b, penthane) as blowing agents could lead to an increase in the thermal conductivity values of 0,03 - 0,04 W/m.°K.

So, with less efficiency, these non-CFC foams will not remain competitive regarding cheaper insulating material such as standard mineral wool and expanded polystyrene.

2.6 Creation of innovative insulating material

Because of the high cost of setting up Research and Development programmes it is necessary to reach very low values of thermal conductivity (maximum : 0,010 W/m.°K). With these specifications, research for innovative material has lead to the manufacture of evacuated panels filled with micro-powder.

Nevertheless this material is too far from the standard materials to be developed in the building field. So the first development to be considered is refrigerator insulation in order to increase the interior storage capacity and to use non-CFC insulating material.

Another possible innovative insulating material now being studied in France is transparent insulating material (TIM). On site tests as well as studies on industrial production processes are carried out with german products. Six houses using TIM have been built in the east part of France with a collector storage wall made up of a 16 cm thick concrete wall and a 10 cm thick TIM. The U-value is 0,75 W/m²°K which is equal to the U-value of the same concrete wall insulated on its external surface by 4 cm of glass wool.

Monitoring these houses will allow us to compare them to the results of the simulation study, done during the design stage. This study showed good solar gains (about 40 %) compared to a similar building with 4 cm thick external insulation.

CONCLUSION

To meet today's requirements, insulation materials and components have been greatly modified or totally re-designed during the last fifteen years.

Very efficient solutions have been developed. Their use has lead to important improvements by reducing heat losses through the envelope by 35 to 45 %.

More research is in progress. The wide application of new techniques in masonry where changes are very long to occur is a permanent objective for the Ademe in order to contribute to stabilize the energy consumption of the building sector.

Figure 1 : GV-value for a dwelling located near Paris (W/°K)

	Individual House (100 m²)		Apartment building (80 m²)	
	Electric space heating	Non-electric space heating	Electric space heating	Non-electric space heating
1974 - 1977	362	362	170	170
1977 - 1982	300	362	150	170
1982 - 1989	225	237	120	130
since 1989	205	227	108	116
GV-value decrease between 1974 and 1989	43,4 %	37 %	36 %	32 %

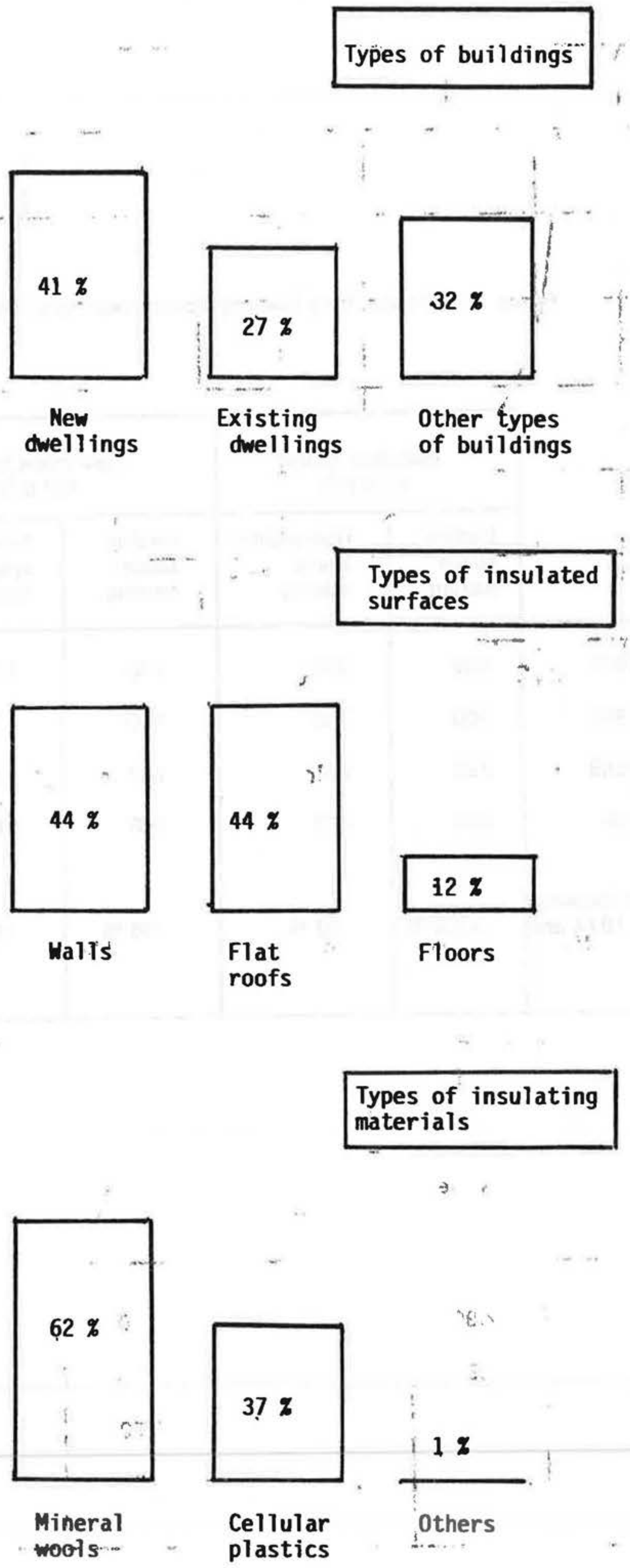


Fig. 2 : Uses of insulating materials

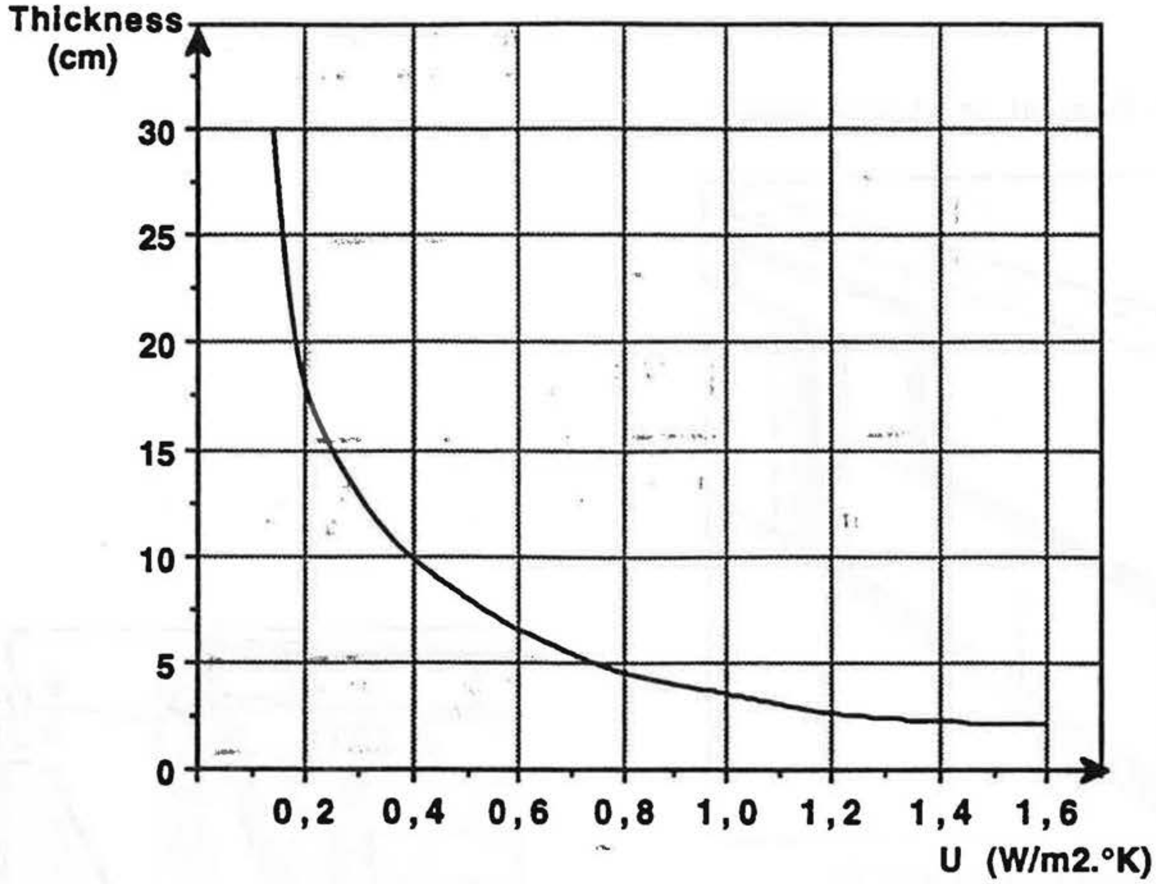
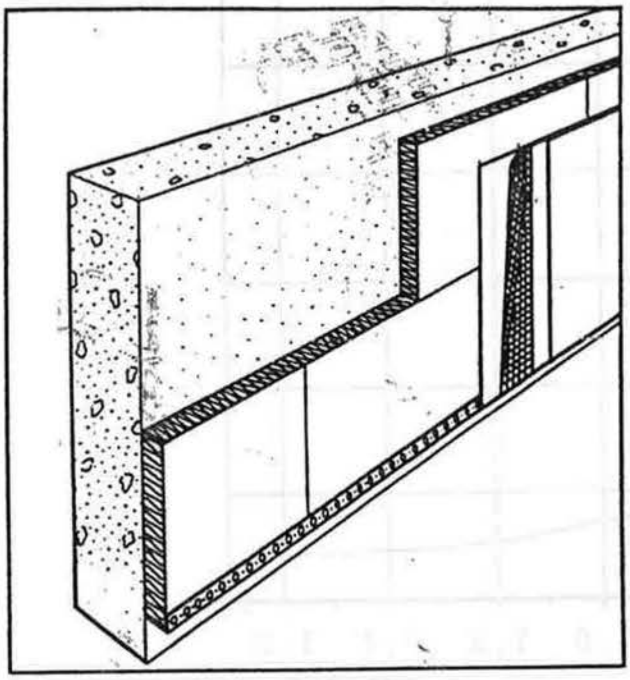


Figure 3 : **U-value versus thickness for an insulating material (λ = 0,04 W/m.°K)**

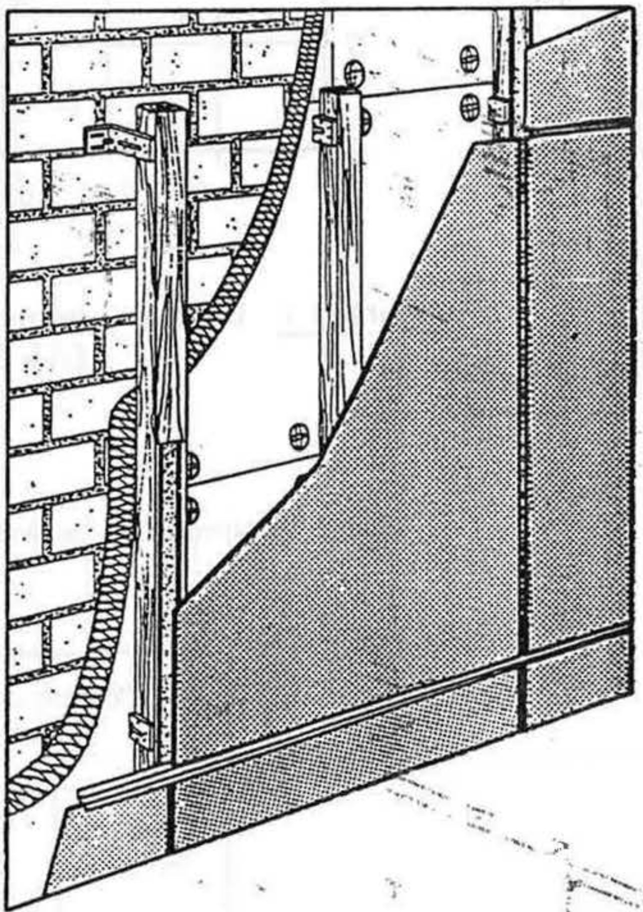
Figure 4 : Maximum R-values and U-values for an individual house located near Paris

	Electric space heating		Non-electric space heating	
	R-value (m^2°K/W)	U-value (W/m^2°K)	R-value (m^2°K/W)	U-value (W/m^2°K)
Walls	2.90	0.32	2.40	0.40
Roof	6.50	0.15	6.50	0.15
Floor	3.00	0.30	2.70	0.35
Windows	0.35	2.00	0.25	2.50

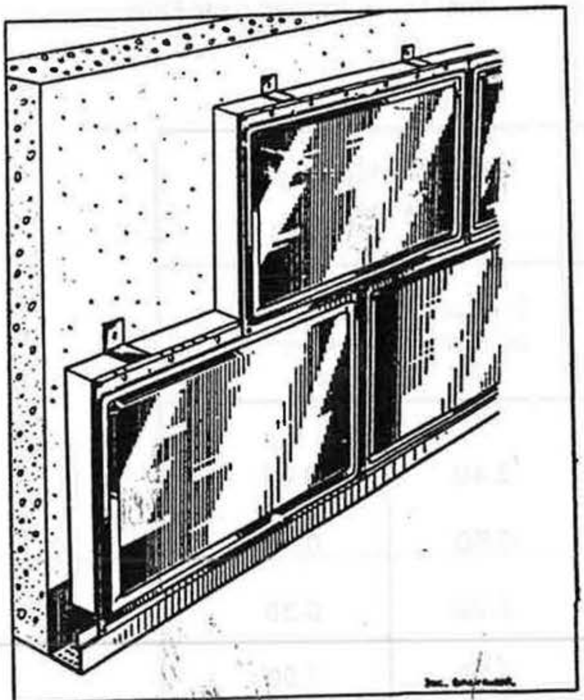
Figure 5 : External insulation systems



Facing on insulating materials



Cladding panels in conjunction with thermal insulation



Prefabricated cladding panels

Figure 6 : Insulating blocks for masonry