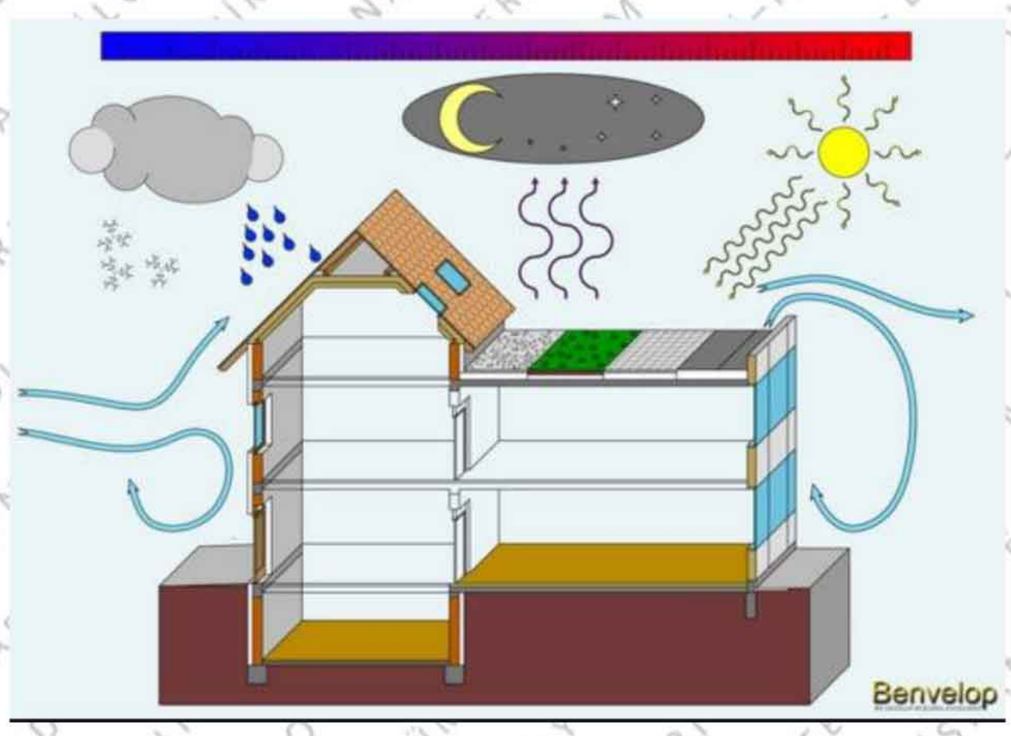
YILDIZ TECHNICAL UNIVERSITY – DEPARTMENT OF ARCHITECTURE
2017 -2018 ACADEMIC YEAR – SPRING SEMESTER
BUILDING MATERIALS LECTURE NOTES / Dr. Polat DARÇIN

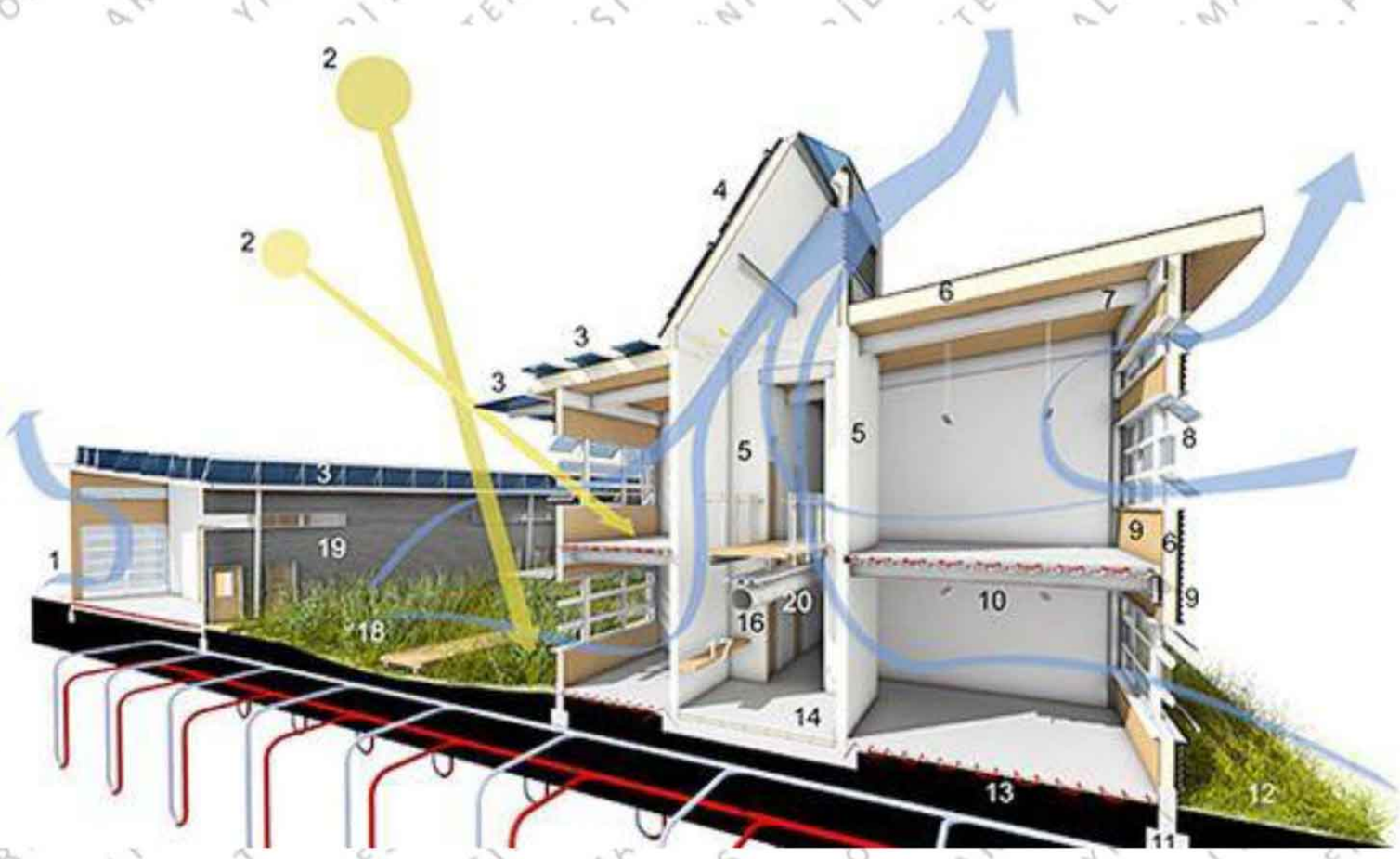
INSULATIONS

Humans, in order to maintain a healthy and good life, require re-organized living spaces compatible to their needs. By separating a part of the natural environment with an envelope (in other terms: by generating a man-made environment), they can gain the necessary living spaces bearing essential living conditions. Based on this statement, **the primal function** of a building is **to offer a healthy and safe living environment** to its users by **protecting them from the negative features** of natural environment (Balanlı, 1997).



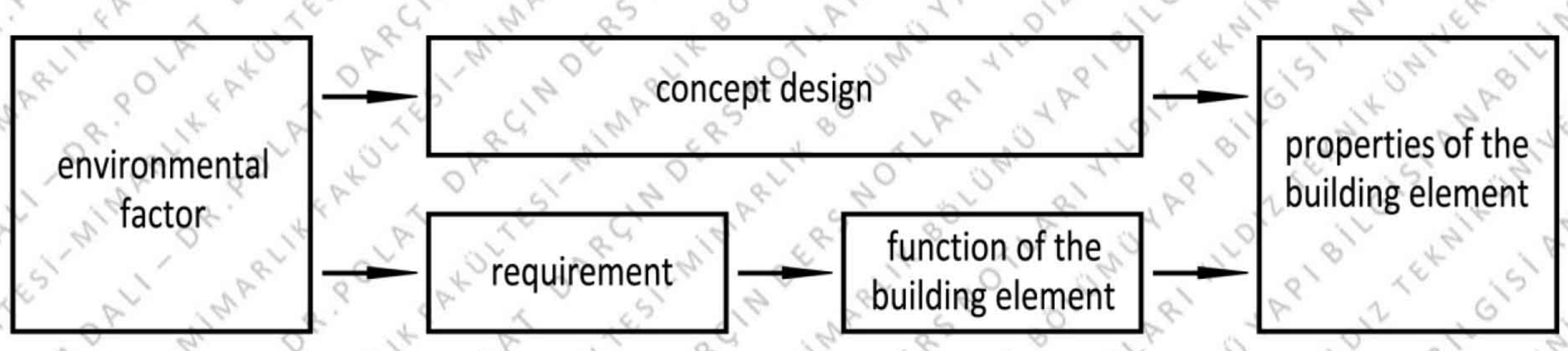
All the spaces of a building (including building units) are formed by **building elements**, which are defined as integral products, composed to **physically meet one or some of the functions of a building** (e.g. walls, floors, etc.) (Balanlı, 1997). Building elements are formed with building **materials**, **pieces** and **components** which are put together in order to impose a specific element with one or more functions that will eventually be owned by building itself.

A building has an interactive and mutually influencing relationship with its outdoor and indoor environments. Due to this relationship, in all stages of building, there is a mutual interaction between the building, its users and other entities of indoor environment and entities of its outdoor environment.



All the factors effecting the environments of building are called environmental factors. Each factor

or combination of different factors may cause a requirement and requirements can be used to determine functions. The main functions of a building are met by the building elements. Furthermore, a concept design can be constituted according to the research about environmental factors. Consequently, the first step for the decisions about product selection is the determination of functions and aesthetical features of building elements according to the pre-design research and concept design decisions. The characteristics of building elements can be revealed based on their functions and aesthetical features and all the materials, pieces and / or components can be determined to materialize these building elements.



For instance, in order to determine one of the functions of a wall separating outdoor and indoor environments of a bedroom, an architect should start with the research for environmental factors mutually relating indoor and outdoor environments of this bedroom unit. If there is a noise of 60 dB in the outdoor environment, the requirement of the user in this bedroom is to sleep in max. 10 dB of acoustic ambience. According to this, one of the functions of bedroom wall can be determined as to present min. 50 dB of soundproofing. In order to achieve this function, this wall should be designed accordingly.

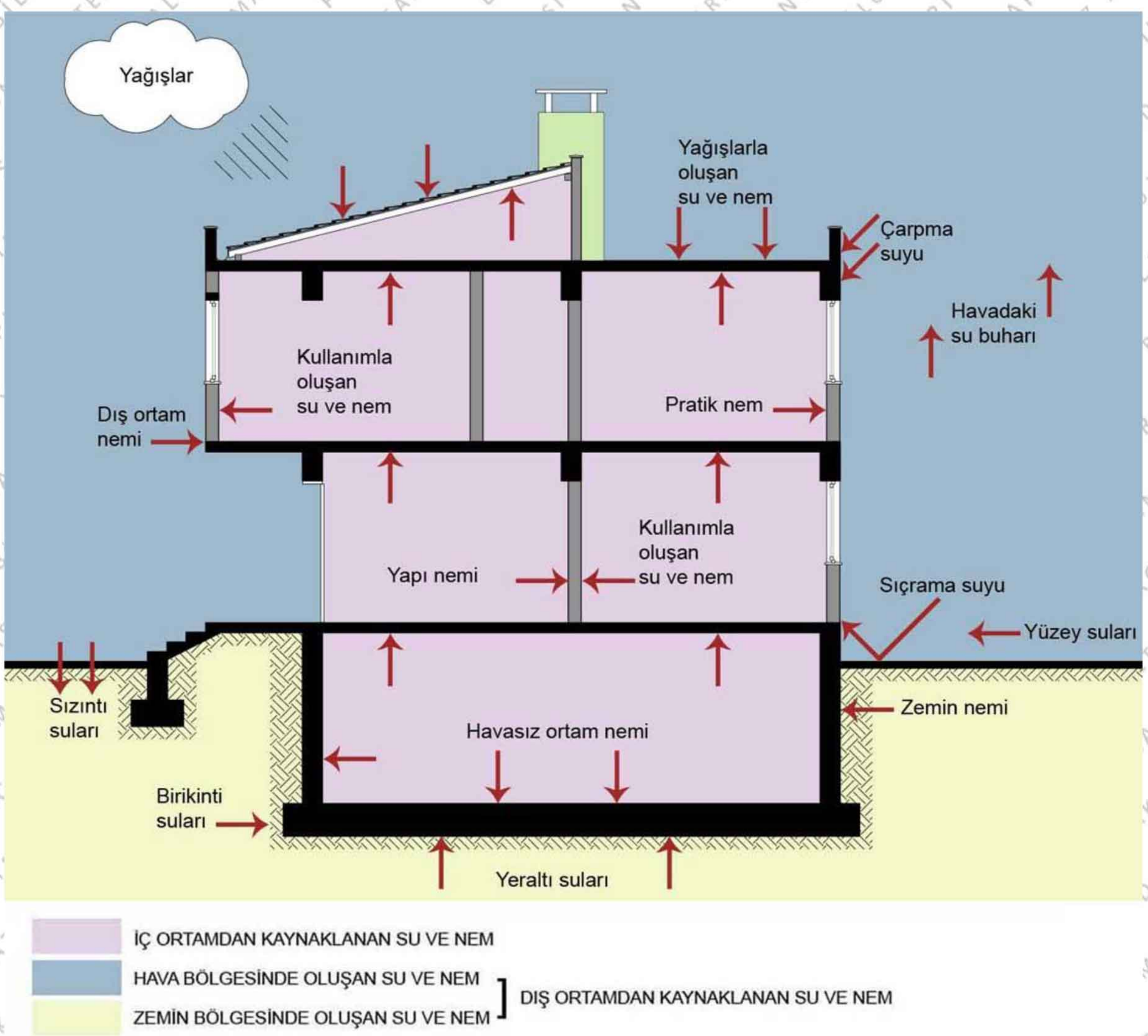
environmental factor	**requirement of the user**	**function of the building element (wall)**	**one of the properties of this building element**
60 dB of outdoor noise level	to sleep in 10 dB of acoustic ambience	to supply 50 dB of soundproofing	to contain a component for designated soundproofing

In case of a negative condition (such as cold or hot air temperatures, noise, water, humidity, X-rays, fire, etc.), which may affect the building products or the users adversely, being present in outdoor or indoor environment of the building, the building elements (walls, floors, foundations, roofs, etc.) should be designed with proper building pieces and components to protect the other building products and the users from that negative condition.

WATER INSULATION PRODUCTS

According to the environmental factors, if there is water in liquid or gas state which may affect the building and indoor spaces (therefore occupants) adversely, the building elements which are in touch with water directly and separating the other building products and units from it (if the surfaces of the envelope are not completely vertical, if they are positioned with an acute angle to horizontal surfaces, then it means that precipitation may accumulate and stay still for a certain period of time) must be insulated against water. With this insulation, the building products and spaces can be protected.

Water, in liquid state, may be present in outdoor environment of a building via **precipitations** (rain, snow, etc.) which can affect the **roof** and **outer walls** and as the **ground water** which can affect the **foundations**. There is also water in some of the indoor environments such as **bathrooms**, **kitchens** and **indoor pools**, etc. In this case, **floors** and **inner walls** will be affected. For each type of water, the related building element and its components or pieces should be designed with proper materials and should be protected from water with proper insulation products.



According to the waterproofing techniques, there are two major groups:

- waterproofing of the surface of the building pieces / components with
  - membranes / sheets (products which are laid, glued or nailed over building products).
  - coating products (products which are coated by painting, spreading, etc. on building products).
- waterproofing the building pieces / components structurally with impervious / waterproofing admixtures.

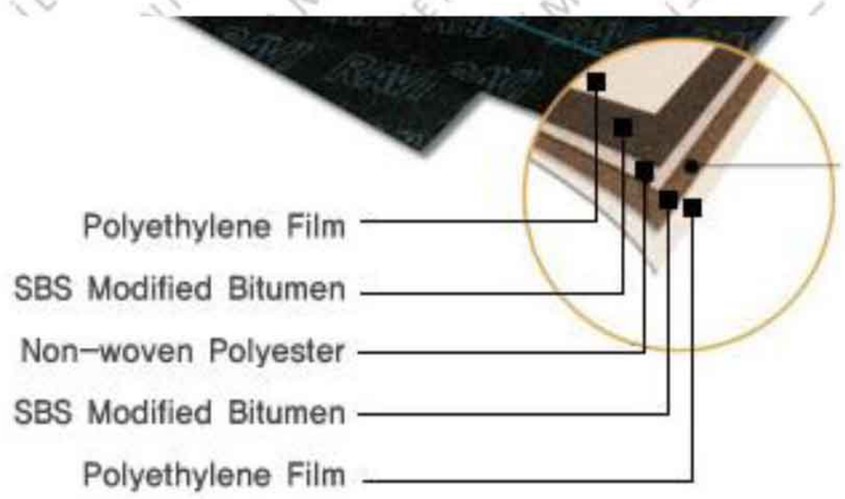
Also some products are used to restrain the water leakage between the joints of two building products.

Waterproofing membranes can be made of

- bitumen or
- plastic

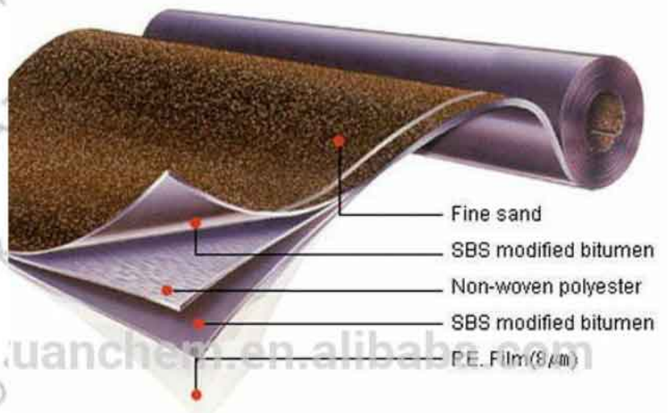
sheets.

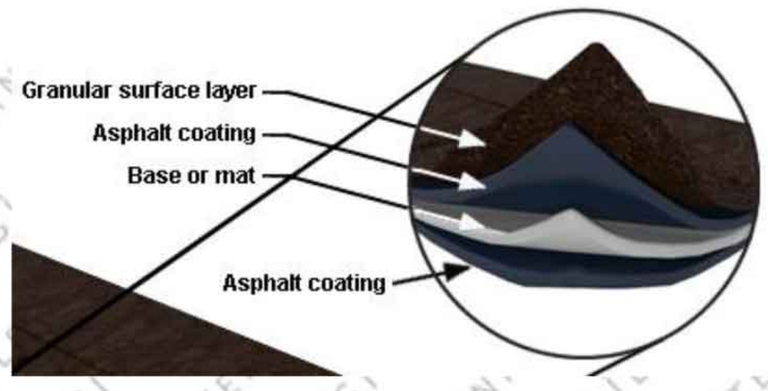
Bitumen sheets are manufactured by running refined bitumen on to with hessian, fiber or mineral fiber bases into sheets of different thicknesses and qualities. Base works to reinforce the soft bitumen layers to make the sheets more stabile against tensile stress. These sheets are used for damp proof courses. These can be bent without cracking.



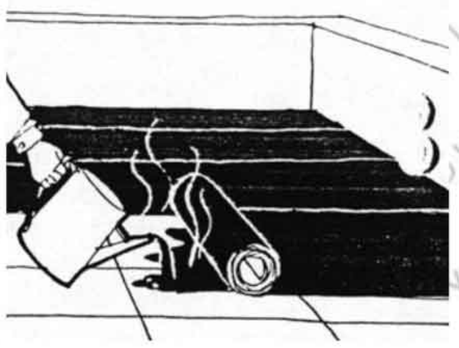
To increase the performance of the bitumen layers, some chemical interventions can be made to change its properties. There are two types of modified bitumen: oxidized bitumen (blown asphalt) which is made by blowing the molded bitumen with high temperature air and polymer bitumen which is obtained by mixing the bitumen with thermoplastic resins.

Also the surfaces of bitumen sheets can be covered with different materials such as polyethylene films, fine sand, mineral splinter or metal foil.



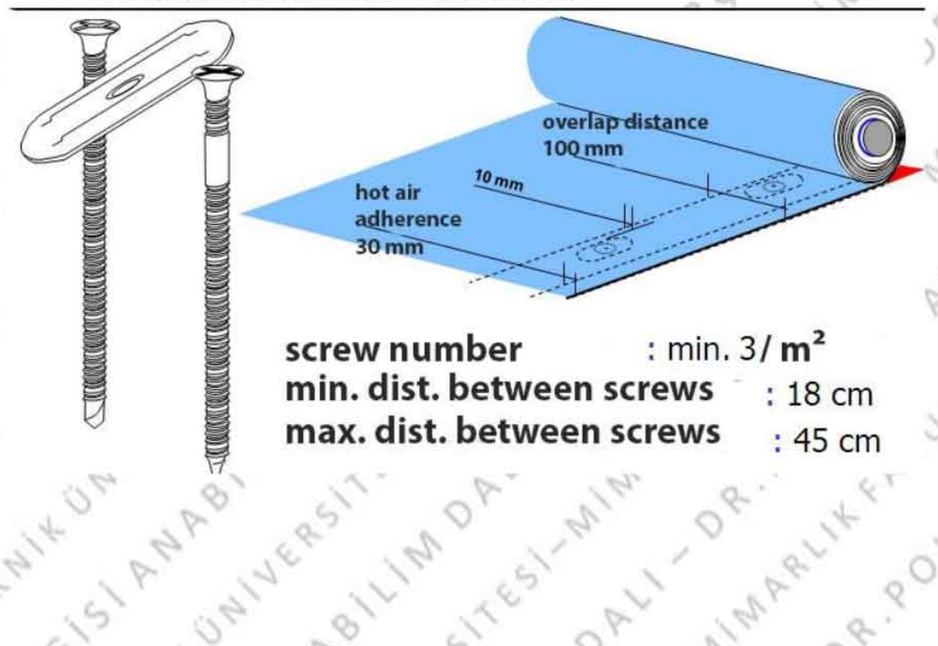


Oxidized bitumen sheets must be applied at least three layers and can be adhered with hot asphalt.



Polymer modified bitumen sheets (2, 3 or 4 mm thickness) are applied at least two layers and can be adhered with blowpipe / welding torch or with hot asphalt. According to the type of the thermoplastic resin, there are two different polymer modified bitumen sheets: plastomeric (with APP [atactic polypropylene] additives) or elastomeric (with SBS [styrene-butadiene-styrene] additives). Plastomeric polymer modified bitumen sheets are applied with blowpipe and can be used in hot climates. Elastomeric polymer modified bitumen sheets are applied with both blowpipe and hot asphat and can be used in cold climates.

Plastic sheets can be made of plastic or rubber and they may or may not have a base layer. Their thickness is 1,2 – 2 mm. These sheets can be laid unattached, they can be applied to the surfaces mechanically (i.e. adhered with special adhesives, stapled, etc.) and with using hot air, only one layer. The plastics that can be used for this kind of sheets are PVC (polyvinylchloride), TPO (thermoplastic polyolefin), EPDM (ethylene polypropylene di-monomer), HDPE (high density poly ethylene), etc.



This kind of bitumen or plastic sheets is not vapor permeable (they are vapor proof). But there are special plastic membranes for waterproofing which can allow vapor to pass through. These membranes generally consist of three layers. Middle layer is a plastic film which has microscopic pores to let the vapor molecules pass but hold the water molecules which are bigger. Upper and lower layers are made of polypropylene for both to make the membrane strong and to protect the middle layer.

Coating products for waterproofing building components can be cement, acrylic, bitumen or polymer based and placed via painting, spraying or troweling.

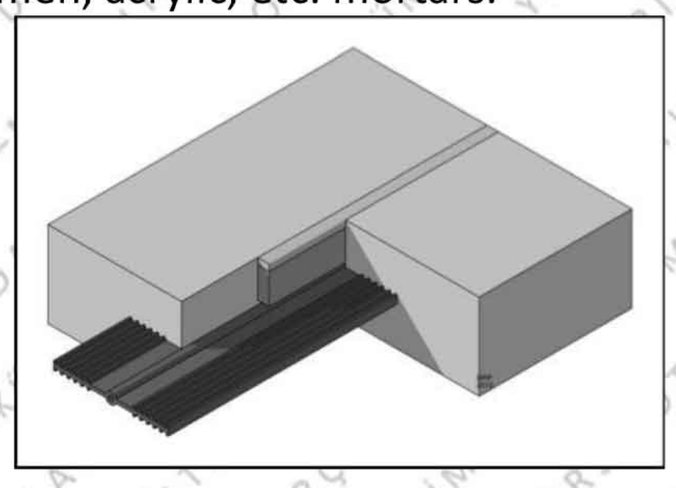
Bitumen based undercoating can be applied over a smooth concrete surface (rc floors, walls, etc. or cement based leveling screed) with a brush. This undercoat will help the bitumen waterproofing sheets to adhere the surface properly.

polymer based waterproofing products

Waterproofing admixtures can be used depending on the function of the concrete and the nature of its exposure. As a naturally porous material, though and one that is prone to cracking, concrete is vulnerable to water infiltrations. Waterproofing admixtures reduce concrete's permeability. One of the additive categories for waterproofing consists of hydrophobic or water repellent chemicals derived from soaps or fatty acids, vegetable oils and petroleum. These materials form a water repellent layer along pores in the concrete, but the pores themselves remain open. The other category is finely divided solids – either inert or chemically active fillers such as talc, siliceous powders, hydrocarbon resins and coal-tar pitches. These materials densify the concrete and physically limit the passage of water through the pores.

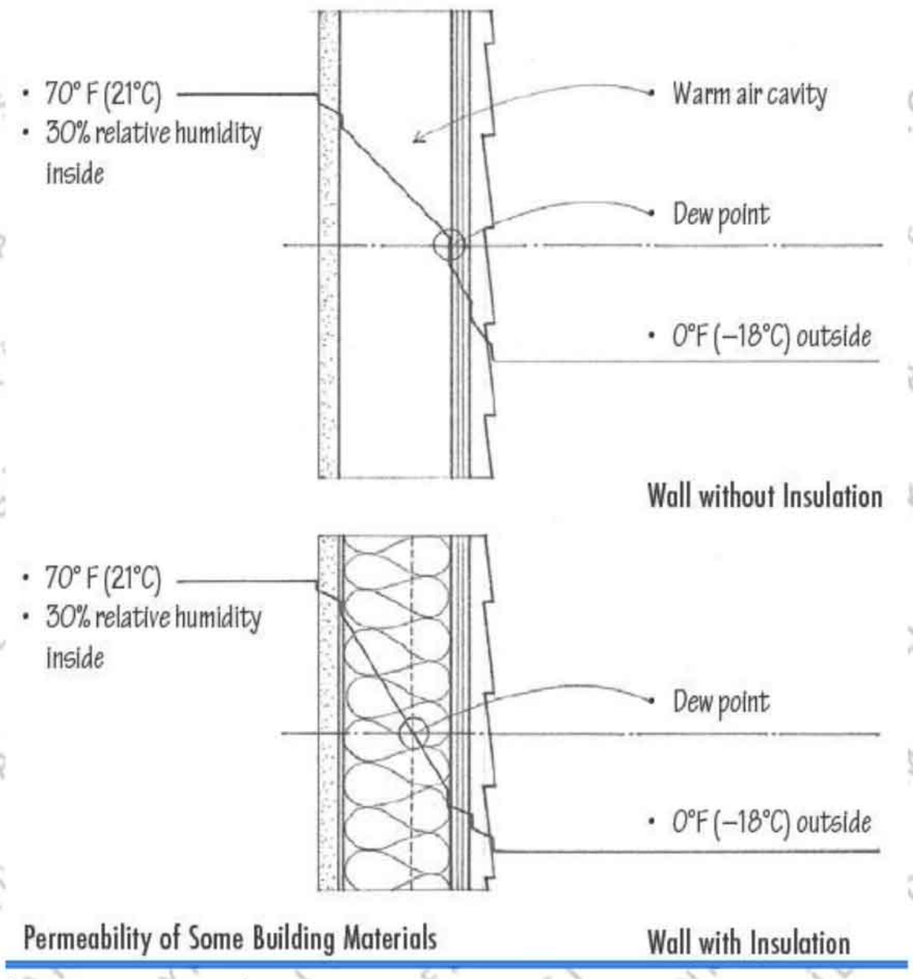
Similarly, timber and metal building products should be protected against water damage with proper covering or impregnation techniques and materials.

Joint fillers can be PVC, synthetic rubber, etc. elastic profiles and bitumen, acrylic, etc. mortars.



INSULATION AGAINST HUMIDITY

Moisture is normally present in the air as water vapor. Evaporation from occupants and equipment can raise the humidity of the air in a building. This moisture vapor will transform itself into a liquid state or condense when the air in which it exists becomes completely saturated with the entire vapor it can hold and reaches its dew point temperature. Warm air is capable of holding more moisture vapor and has a higher dew point than cooler air. Because it is a gas, moisture vapor always migrates from high to lower pressure areas. This normally means it tends to diffuse from the higher humidity levels of a building's interior toward the lower humidity levels outside. This flow is reversed when hot, humid conditions exist outdoors and a building's interior spaces are cooler. Most building materials offer little resistance to this passage of



(Ching, 2008)

moisture vapor. If the moisture vapor comes into contact with a cool surface whose temperature is at or below the dew point of the air, it will condense.

Vapor Barriers and Equalizers

These products are generally made of

- metal foils such as aluminum, copper, etc. covered with bitumen sheets on both sides,
- felts, glass tissue, burlap saturated with bitumen,
- plastic or rubber layers covered with bitumen or asphalt

to hold the water vapor through upper parts of the section. If the water vapor level is high due to the function (like bathrooms, kitchens, etc.) then these products must be used with vapor equalizers to spread the vapor to a larger surface and decrease the vapor pressure level in order to protect upper layers.

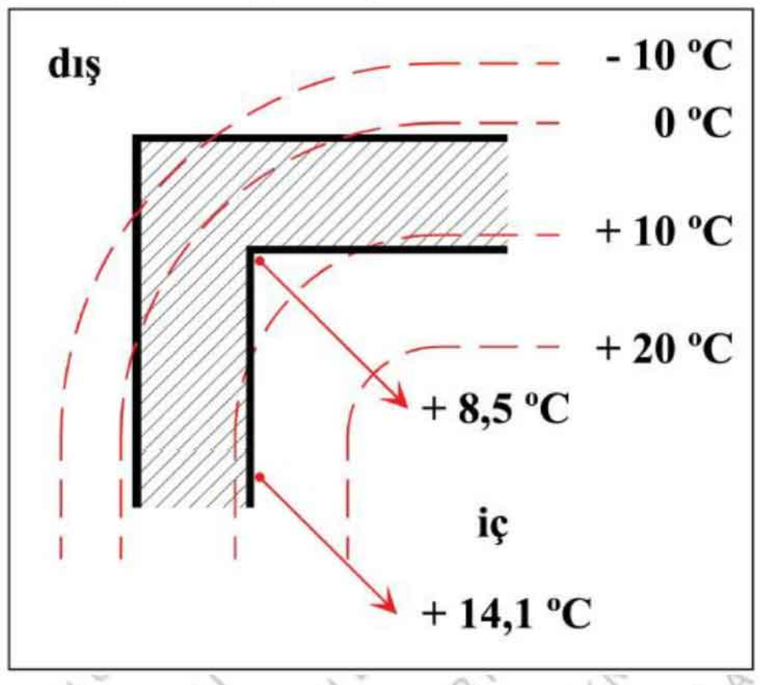
Also blocked vapor should be drained out via designing a proper ventilation.

(Avlar, 2005)

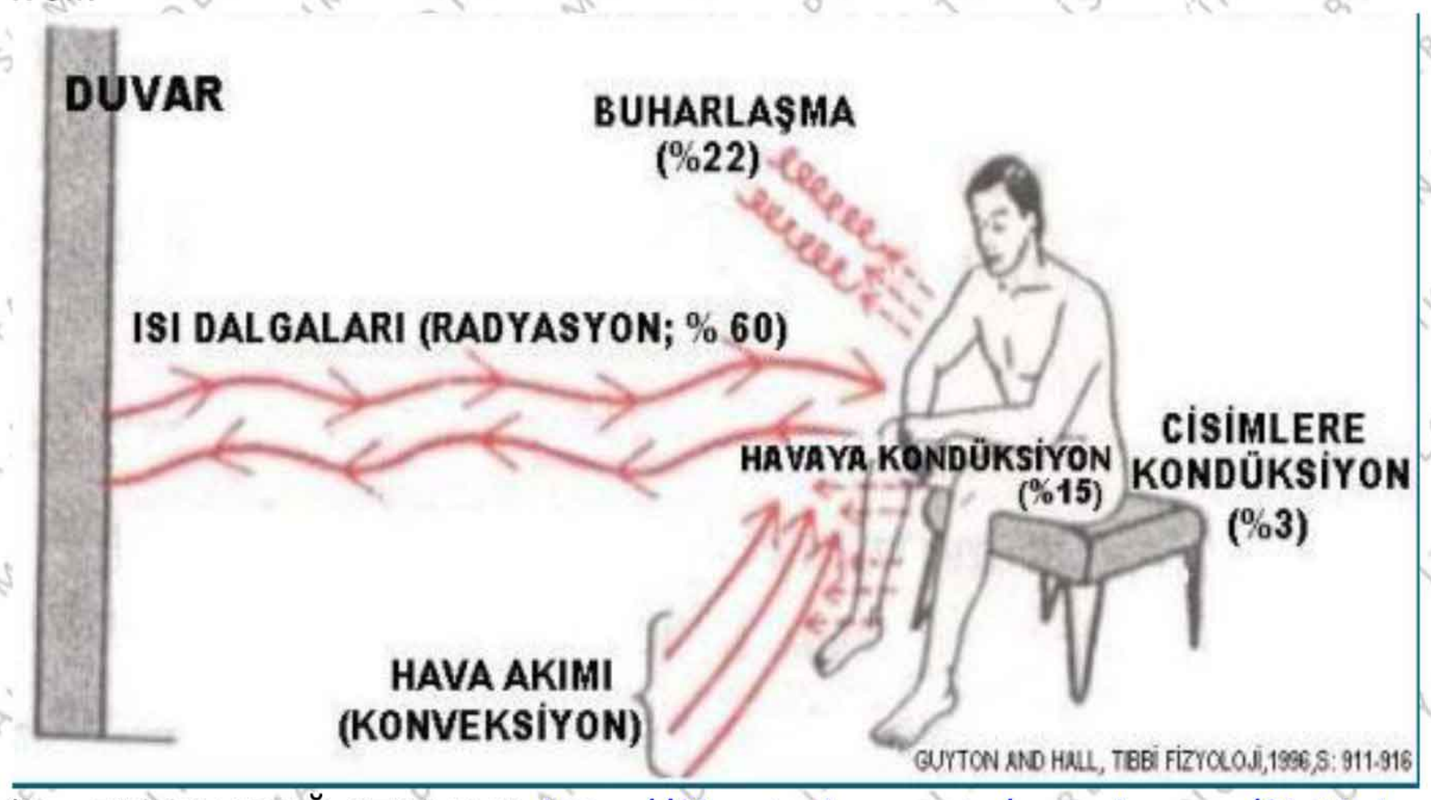
HEAT INSULATION PRODUCTS

All the surfaces of the envelope, which creates a barrier between outdoor and indoor environments, must be insulated against heat transfer to avoid heat losses during the cold session and unwanted heat gains during the hot session. This principle is also important between two neighbor indoor spaces with different temperature ambiences.

Heat transfer starts between human body and surfaces of spaces at different temperatures when the body touches a certain surface via conduction, between the indoor air and the body via convection and between the surface and the body via radiation. It is not enough for the indoor air to be at a certain temperature suitable for humans living, because heat transfer between the body and the surfaces of floors and walls via radiation has the most percentage of occurring then conduction and convection. The temperatures of the surfaces must be suitable as



well.



(Dr. Elif ÇALIDAĞ ATAMAN, http://file.atuder.org.tr/_atuder.org/fileUpload/3MG2dGS12pEE.pdf)

Due to these relationships between air, surface and body temperatures and because of the condensation probabilities through different components of building elements, the selection of heat insulation products and their properties (such as thickness, etc.) must be determined according to calculations specified in building physics. To avoid condensation of water vapor through the section of building elements, the temperature of the air should be maintained at the room temperature. To ensure this, all the components of building elements should let the humid air diffuse and the heat insulation should be placed on the colder side.

To decide and select the proper heat insulation product, the

- thermal transmittance (U) or conductivity (λ),
- water vapor diffusion resistance (μ),
- fire resistance (A1 [best resistance], A2, B, C, D, E, F [worst resistance]),
- water absorption,
- compression strength,
- economic

values of the heat insulation products must be considered along with the relation between these products and other pieces or components of the building element which must insulate the heat.

heat insulation products	**properties**	**image**
Glass wool is a flexible inorganic fibrous open porous material made of silica sand.	λ = 0,035 – 0,050 W/m.K; μ= 1; fire resistance= A1, A2; water absorption= %3 – 10; compression strength = 5 – 500 kPa	

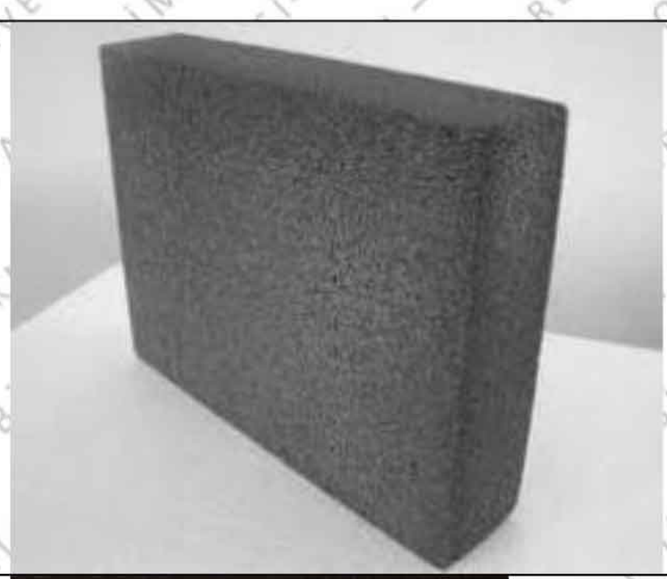
Rock wool is a flexible inorganic fibrous open porous material made of basalt and diabase stones.	λ = 0,035 – 0,050 W/m.K; μ= 1; fire resistance= A1, A2; water absorption = %2 – 10; compression strength = 5 – 500 kPa	

EPS (expanded polystyrene) foam board is a closed porous material made of polystyrene.	λ = 0,035 – 0,040 W/m.K;
	μ= 20 - 100;
	fire resistance= D, E;
	water absorption = %1 - 5;
	compression strength = 30 – 500 kPa
		 

XPS (extruded polystyrene) foam board is a closed porous material made of polystyrene. Some boards have channels on the surface.	λ = 0,030 – 0,040 W/m.K; μ= 80 - 250; fire resistance= D, E; water absorption = %0 – 0,5; compression strength = 100 – 1000 kPa	

Rigid polyurethane foam	λ = 0,025 – 0,040 W/m.K;
	μ= 30 - 100;
	fire resistance= E, F;
	water absorption = %3-5;
	compression strength = 25 – 800 kPa
		

Wood fiber is mostly used as panels laminated to one or both sides of XPS or glass / rock wool.	λ = 0,065 – 0,090 W/m.K; μ= 2 - 5; fire resistance= B; compression strength = 20 - 1000 kPa	

Glass foam is a closed porous material made of cellular filling materials combined with waste glass particles	λ = 0,045 – 0,060 W/m.K;
	μ=∞;
	fire resistance= A;
	water absorption = % 0;
	compression strength = 430 – 8800 kPa
		

Expanded perlite is made by heating the perlite (composition of silica and aluminum) to form boards or granules.	λ = 0,045 – 0,065 W/m.K; μ=5; fire resistance= A;	
Wood fiber boards are made of wood particles.	λ = 0,035 – 0,070 W/m.K; μ= 5; fire resistance= E; compression strength = 5 – 100 kPa	
Mineral wool (brand name: Natur Board POD Classic ECOSE)	λ: 0,039 W / m.K compression strength: 2, 5, 10 kPa fire resistance: A1	
ACC heat insulation boards	λ = 0,05 W/m.K; fire resistance: A1 μ: 3 compression strength = ≥0,35 N/mm² (http://www.ytong.com.tr/)	

PRODUCTS RELATED TO SOUND

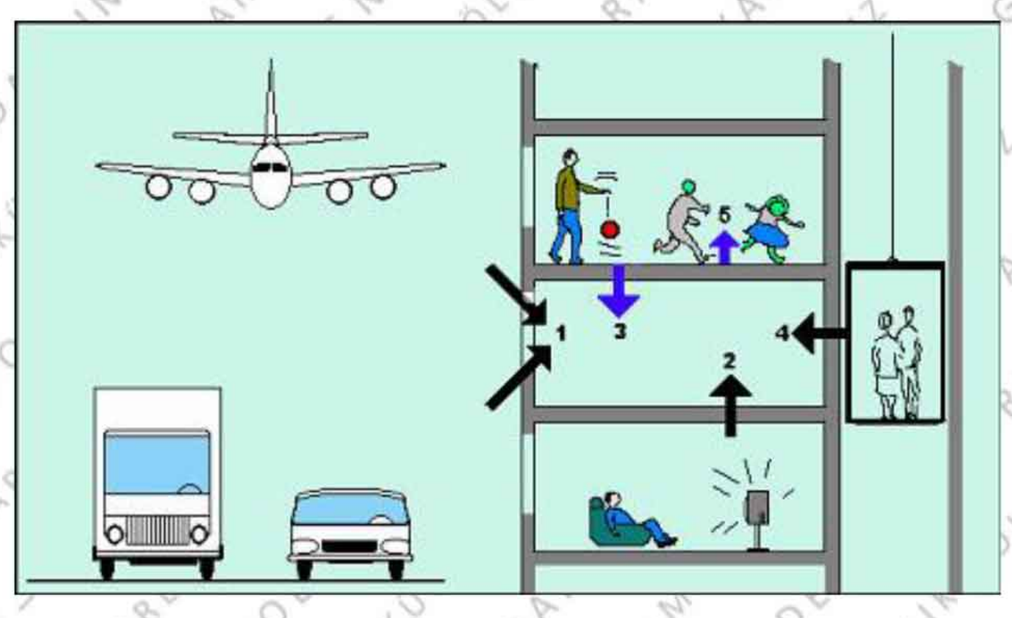
The requirements of the user related to sound can be categorized as controlling of the noise which is defined as any unwanted / disturbing sounds and perception of the sound (speech, music, etc.) easily in an indoor space by the listener. In building physics, the control of the noise is examined under building acoustics, the perception of the sound is examined under room acoustics.

Sound is a vibration that propagates as a typically audible mechanical wave of pressure and displacement, through a transmission medium such as air or water. Sound can be identified with its three features:

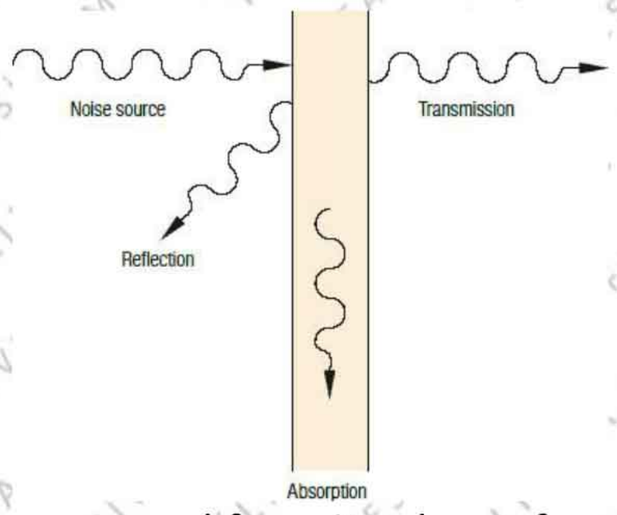
- its frequency: the pitch of the sound (high – low pitches)
- its amplitude or intensity (e.g. whispering or shouting)
- its timbre (e.g. the sound of a piano or a violin).

The control of noise can be managed at the source of the noise, between the source and the receiver or at the receiver.

The sound (or noise) can be transmitted to the receiver via air (air borne noise) or through the structure of building elements (structure borne noise). Air borne sound arises as the air molecules start to vibrate around the source and transmitted through the vibrating air molecules (such as playing a musical instrument). Structure borne sound forms in a solid building product and transmitted through connected products of building.



When a sound wave encounters a solid, depending on the properties of material and its surface, some of the energy is reflected, some is absorbed and some will be transferred to the other side. Also, any gaps in this solid will let the sound waves pass through air molecules.



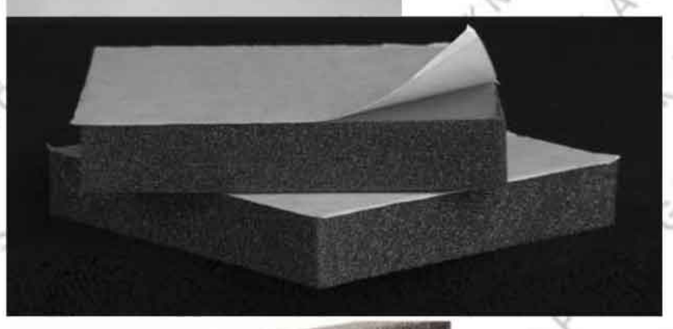
The most important way of transmission of air borne sound from its place of source to the neighbor space is the mass vibration of the separator building element. Sound waves cause a mass vibration of the whole wall, door, floor, etc. surfaces. Low pitch sounds can manage a better vibration due to their frequencies then the higher pitches. In order to control the transmission of sound, all the gaps must be filled and the vibrating movement of the element must be prevented. Instead of designing a very heavy element, a better solution is to designing two masses with an air gap between. Nor the thicknesses of two messes should not be same; neither there should not be ratios between their thicknesses such as 1/2, 1/3.

Also airborne sound can be absorbed by building products with open pores. Sound waves lose energy during the vibration of air in the tiny gaps on the surface of noise absorbing products as the some of the energy transforms into heat energy. For the selection of proper sound absorbing products and their properties, calculation under building acoustics should be made. Some of the sound absorbing

products are:

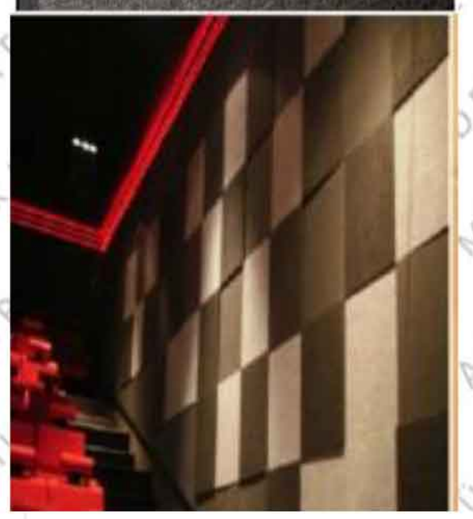
perforated galvanized steel or aluminum boards with glass wool backing (http://www.kineticsnoise.com/industrial/knp.html)

polyurethane foam boards (6 – 51 mm thickness)



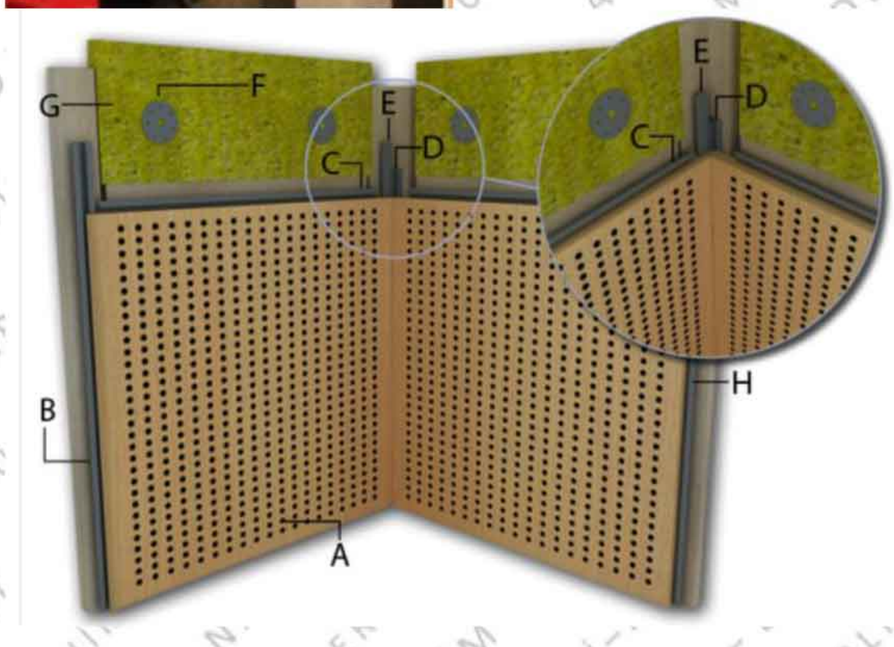
rigid fiberglass boards with a fabric cover

high density glass wool boards with glass tissue covering (20-40 mm thickness)



perforated solid or engineered timber boards with glass wool backing

(http://www.sesyalitimsungerleri.com/delikli-derzli-akustik-ahsap-duvar-panelleri.html)



To control structure / impact borne noise, the transmission of sound through solid connected building products must be prevented. The connection of different building elements (such as the connection of a wall to the floors) must be made with an elastic piece (such as glass wool, cork, neoprene, etc.) that will not transmit the vibrations.