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TRANSPARENT THERMO-INSULATING INFLATED PILLOWS/MEMBRANES IN CIVIL ENGINEERING

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This work is dedicated to early deceased professor PhD Ahmet Hadipasic, Prime Minister of Federation of Bosnia and Herzegovina (2003-2007).

ABSTRACT
In this work are shown the advantages of use of transparent thermo-insulating inflated pillows/membranes in civil engineering, made of thin ETFE (Ethylene Tetrafluoro- ethylene) foils. There are given general information about thermo-technical and other characteristics of ETFE foils comparing them with the same characteristics of the other transparent enclosing materials which are being used in civil engineering.
There are described examples of inflated thermo pillows made of ETFE foils which were built in two world famous buildings: Eden Greenhouse / Nicolas Grimshaw and Beijing Water-cube (national center for water sports).
Key words: civil engineering, transparent thermo-insulating materials.

1. INTRODUCTION
The builders are always asked about demands for new materials which will successfully respond to new energetic, ecological, visual, esthetic and other standards. An outstanding achievement was done by successful production of new transparent foil made of EthyleneTetrafluoroethylene (ETFE foil). This foil is being used for making transparent inflated thermo pillows which are effectively built in the most demanding buildings.

2. ETFE TRANSPARENT THERMO-INSULATING FOILS
2.1. ETFE foils basic characteristics
ETFE foils are produced from fluoropolymer granules (Ethylene Tetrafluoroethylen).
The foils have low friction coefficient, high resistance on weather conditions, chemical influences and UV radiation, ignoring humidity absorption, good characteristics on extreme temperatures, and excellent visual and esthetic qualities. They are easy to shape and with possibilities for laminating, sticking, melting, etc. they ensure the widest use of them in contemporary civil engineering.
ETFE foil features are:

- Transparency; transmits more light than glass or other transparent materials(fig.1)

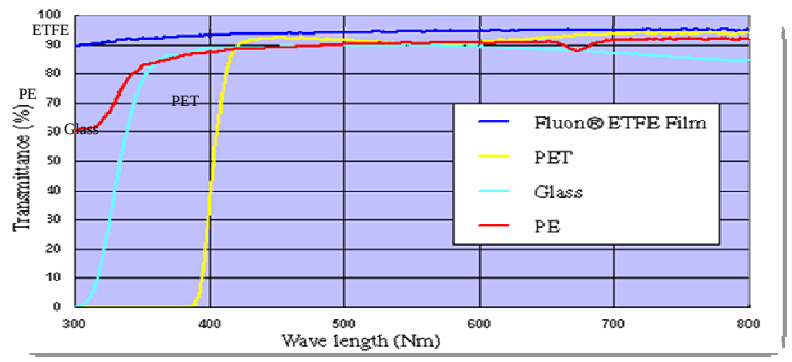

Figure 1.Comparison of light transmittance of ETFE foil and other transparent materials[3]

- ETFE foils have 1% of the weight of the equivalent size glass panel and there are needed smaller (lighter) metal constructions to bear them
- ETFE foils are recyclable and durable (over 25 years)
- ETFE foils are strong, hard and resisting; each inflated single pillow can sustain the weight of one football team
- ETFE foils are non-stick material, which means they have self-cleaning abilities
- ETFE as high-tech material enables 90% utilization of solar energy which will be accumulated in structural zones of ETFE foils and warm up internal space.

Table 1. Thermo-technical characteristics of ETFE foils and the other transparent materials[4]

°C	ETFE (foils)	PVF	PVC	PET
Melting point	260	195	82	260
Decomposing temperature	360	220	200	350
Steadiness temperature	150-180	100	60	80

Table 2. Comparison of chemical resistance of ETFE foils and the other materials [4]

	ETFE (foils)	PVF	PP	PVC
Acids	Excellent	Weak	Good	Good
Bases	Excellent	Good	Good	Good
Salts	Excellent	Weak	Weak	Weak

3.THE USE OF ETFE – TRANSPARENT THERMO FOILS

3.1. ETFE – Transparent thermo-insulating inflated pillows/membranes

ETFE pillows or membranes have found the most interesting use in the civil engineering. They are utilized for covering big surfaces instead of glass.
The glass would be too heavy, inflexible and too dangerous on these spans.

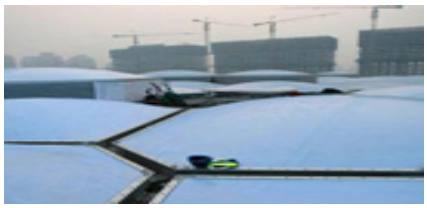

Figure 2. ETFE pillows/membranes [2]

The pillows are multi-layer and have 1 or 2 air-layers, what enables maximal thermo-insulation. The quantity of the air in the pillows can be adjusted. During the warm days they can be pumped out as the air spreads and during cold weather the air is pumped in, so the building behaves as alive.

3.1.1. Greenhouse Eden / Nicolas Grimshaw

Eden is the largest greenhouse in the world and at the same time an exhibition of global bio-diversity and its connection with humans. The system consists of series of connected geodesic domes, climatically controlled and situated in former porcelain- clay mine landscape in Cornwall.
The series of eight mutually imbued geodesic domes, with total surface of 2.2 acres (the largest and the most lightweight structure of that kind ever made), was constructed of self-bearing hexagonal frames made of tubular steel. The hexagons have different size depending on dome dimensions, which enables an easy adjusting to the uneven ground topography. The largest hexagon has 11m span and thanks to the additional sub-construction the diameter of the frame's thickest pipe is less than 20cm, that gives spider net filigree character to the whole structure.

Figure 3. Greenhouse Eden / Nicolas Grimshaw, the use of ETFE-pillows [3]

There was chosen an organic farm because it suits plants and it's easy to adjust it to the terrain. Like the most beautiful structures from the plant's and animal's world, there was made system based on the principle of maximal efficiency with minimal resources.

3.1.2. National center for water sports "Water cube" Beijing – China

The "Water cube" was built for the needs of the Olympic Games 2008 and according to the many people it became new symbol of Beijing. It is placed on the southern part of unique Olympic complex, nearby national stadium which is also called "Bird's nest", because of its specific shape. Water center has an area of about 6.95 acres and 17,000 audience seats. National swimming center looks like semi-transparent cube with balloons
widespread on whole surface and actually it has a structure similar to H2O.
Regarding that Gobi desert is near and Beijing water problems, the building has underground basins to collect rain-water, by which are supplied swimming pools.
They save on heating and cooling, because the cube has system on its walls that breaks up the Sun's rays and which adjusts for heating in the winter and for cooling in the summer. The building is in the shape of cube and is especially attractive when the Sun shines on water "bubbles". The Sun's rays which pass inside through the airy roof's construction make the feeling of peace and easiness. Its surface is 80,000 m².(fig.4.).

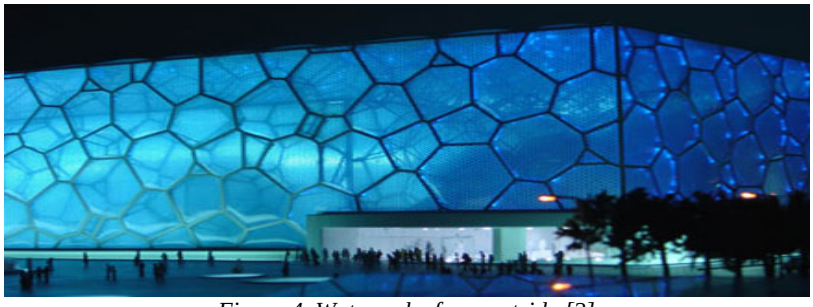

Figure 4. Water cube from outside [2]

4. CONCLUSION

- ETFE transparent thermo-insulating inflated pillows/membranes are new enclosing transparent material which has important advantages in relation to the other enclosing transparent materials, especially glass.
- ETFE inflated pillows have only 1% of the weight of the equivalent size glass panel. There are needed lighter metal constructions for its bearing, they have ability of self-cleaning and they are recyclable and durable (over 25 years).
- The imperfection of this material is a duration of 25-30 years, and that is its biggest deficiency if we take in consideration that the glass has unlimited duration.
- With successful solution to extend ETFE pillows duration, we can expect it to become irreplaceable transparent material and to push into the background massive constructions in the important sector of civil engineering and on that way to give more creativity to the architects.

5. REFERENCES

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[2] www.water-cube.com
[3] www.etfe.com
[4] www.new-material.com