EVALUATION OF CHANGES IN CONSTRUCTION MATERIALS USED IN COLD STORAGE SYSTEMS FOR APPLES IN TURKEY, WITH REGARD TO ENERGY SAVING

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Abstract

Turkey has a high potential for apple production, and the need to preserve the quality of fruit on the market longer and better has accelerated the development of cold storage technology. In recent years, facilities built to store apples have undergone changes both in cooling systems and construction characteristics. This study examines the changes over time in the construction of cold storage facilities used to store apples, and evaluates the heat transfer properties of the construction materials and thus their energy saving effects.

Keywords

Apple, cold storage system, construction, isolation, energy saving.

Introduction

Apples are produced today in very many varieties in almost every country in the world, and the quantity produced surpasses that of every other type of fruit. In Turkey, apples take first place in fruit production, with between 2.46 106 and 2.51 106 tonnes produced annually in the last few years (2005-2007) (TUİK, 2009). At the same time, modern controlled atmosphere cooling systems have come into use alongside the traditional compressor cooling systems to preserve the quality of apples and other fruits. In this way, the fruit can be stored for a long period, and can be brought to market out of season, so that its market value is enhanced (Unal and Yilmaz, 2008).

Turkey's apple production is centered around Isparta. Isparta's apple production in 2008 was approximately 0.54 106 tonnes, or 22% of Turkey's total apple production. This apple production potential has also stimulated cold storage operation in Isparta, and given it an important place in Turkey. There are at present 60 cold storage facilities for apples in Isparta. Some of these are traditional cold storage built before 2000, and the rest, built after 2000, are modern cold storage facilities (Unal, 2009). This provides the opportunity to compare the construction and cooling systems of the existing traditional and modern cold storage systems. In this way, the cold storage facilities of Isparta can be taken to represent the current condition of cold storage for apples in Turkey as a whole.

In a significant proportion of cold storage facilities used for the storage of fruit such as apples, there are planning and design faults, and insufficient isolation results in considerable energy losses. This means that the facilities cannot be run economically (Gullenoglu, 1988). For this reason, the most economic choice of insulating material and cooling fluid is of utmost importance in the successful planning of cold storage facilities. In order to make such a choice, optimization, that is bringing together all the most economic conditions, is necessary. In this way, expenditure will be reduced in both the planning and the operation of the cold store facility (Heves, 1996).

In providing isolation for the walls of a cold storage facility, the use of expanded polystyrene (EPS) along with briquettes or bricks is recommended as an insulating material (Savas, 1987). It has been stated that the use of polyurethane alongside EPS as an insulating material in cold stores is very suitable, and also that the use of polyurethane provides a large energy saving, and as it also protects from damp, it is eminently suitable as an internal insulating covering (Altinisik, 2006). The use of wall panels made from hard polyurethane in reinforced concrete or steel constructions (see Fig. 1) provides good sound, damp and heat insulation, and is fire-resistant and light (IZOGUL, 2007).

Construction of buildings and cooling systems by companies building cold storage facilities is widespread in Turkey, especially for apple storage. Stores built in the past few years have shown differences in both cooling systems and construction characteristics. This study examines construction changes in cold storage facilities built to store apples, and evaluates their energy-saving qualities.

Material and methods

All sixty cold storage facilities for apples in Isparta, which is the main centre for apple production and storage in Turkey, were taken as material for the study. Firstly, the changes in construction and isolation materials used in building these stores before and after 2000 were examined. The construction details for this evaluation were taken from the interim report of a research project carried out by Unal (2009) in Isparta. Construction and isolation materials used are shown in Figure 1. Later, the total heat transfer coefficients of the construction components of the store were calculated by means of the following equation (TSE, 1998; Sahin and Unal, 2007):

$$U = \frac{1}{\frac{1}{\lambda_i} + \frac{d_1}{\lambda_1} + \frac{d_2}{\lambda_2} + \frac{d_3}{\lambda_3} + \ldots + \frac{d_n}{\lambda_n} + \frac{1}{\lambda_o}} \qquad (1)$$

Findings

Construction Materials Used in Cold Store Facilities

Table 1 shows the distribution by years of materials used in the construction of cold store walls and bring systems.

In bring systems, the ratio of cold storage systems using conventional concrete was 45.0% for those constructed before 2000, and 1.7% for those constructed after 2000, and with a total of 46.7%, this was the most-used material. The ratio of those using prefabricated concrete was 18.3% for those constructed both before and after 2000, giving a total of 36.6% as the second most used material. Least used was steel, with a pre-2000 ratio of 6.7% and 10.0% after 2000, and a total of 16.7%. For wall construction materials, the ratio of cold storage systems construction using briquette was 58.3% before 2000, but fell to 6.7% after 2000 (see Fig. 1). Nevertheless briquette construction was the most frequent with a total ratio of 65%. Polyurethane panels were not used before 2000, but were used at a ratio of 20.0% after 2000, putting them in second place. The ratio of cold storage systems using brick in wall construction was 11.7% before 2000 but only 3.3% afterwards, and the total of 15% put it into third place.

Isolation materials used in the construction of cold storage facilities

The isolation materials used in the various components of the construction (ceiling, walls, and floors) of cold storage facilities are given in Table 2.

The most-used material in cold store ceiling systems was EPS, with a ratio before 2000 of 68.3%, 6.7% after 2000, and a total of 75%. Polyurethane sandwich panels were not used before 2000, but their post-2000 and total ratio of 21.7% puts them in second place. The ratio of cold stores using polyurethane foam was 1.7% both before and after 2000, giving a total of 3.3%, and putting it in third place.

Table 1. Distribution of the cold storages used several materials for construction elements by years

Construction components	Materials	Before 2000		After 2000		Total	
		(No)	(%)	(No)	(%)	(No)	(%)
Bring systems	Conventional concrete	27	45.0	1	1.7	28	46.7
	Prefabricate concrete	11	18.3	11	18.3	22	36.6
	Steel	4	6.7	6	10.0	10	16.7
Total						60	100.0
Walls	Briquette	35	58.3	4	6.7	39	65.0
	Polyurethane sandwich panel	-	-	12	20.0	12	20.0
	Brick	7	11.7	2	3.3	9	15.0
Total						60	100.0

Table 2. Distribution of the cold storages used several isolation materials for construction elements by years

Construction components	Isolation materials	Before 2000		After 2000		Total	
		(No)	(%)	(No)	(%)	(No)	(%)
Ceiling	EPS	41	68.3	4	6.7	45	75.0
	Polyurethane sandwich panel	-	-	13	21.7	13	21.7
	Polyurethane foam	1	1.7	1	1.7	2	3.3
Total						60	100.0
Wall	EPS	40	66.7	6	10.0	46	76.7
	Polyurethane sandwich panel	-	-	12	20.0	12	20.0
	Polyurethane foam	2	3.3	-	-	2	3.3
Total						60	100.0
Floor	EPS	41	68.3	16	26.7	57	95.0
	Polyurethane sandwich panel	-	-	1	1.7	1	1.7
	Polyurethane foam	1	1.7	1	1.7	2	3.3
Total						60	100.0

Of wall isolation materials, EPS was the most used, at a ratio of 66.7% before 2000, 10.0% after 2000, and 76.7% in total. Next came polyurethane sandwich panels, which were not used before 2000, but were used after 2000 and in total at a ratio of 20.0%. Polyurethane foam was not used after 2000; its pre-2000 and total ratio was 3.3%, leaving it in third place. In floors, the most-used insulating material was EPS. Before 2000 it was used at a ratio of 68.3% and at 26.7% after 2000. The total ratio of use was 95.0%. Polyurethane sandwich panels were not used before 2000, but were used at 1.7% after 2000, putting them in second place. Polyurethane foam was used at a ratio of 1.7% both before and after 2000, with the total of 3.3% leaving it in third place.

Heat transfer coefficients of the construction components of cold storage facilities

In order to check whether cold storage have suitable insulation, it is necessary to determine the heat transfer which happens in connection with the heat transfer characteristics of each component of the construction, composed of various construction materials. The heat transfer coefficients (U) of the components (ceiling, wall and floor) of the cold storages used to store apples (see Fig. 1) were calculated using thermal conductivity values (λ) and are given in Table 3. As the floors were made of a single type of material composition, the U value for this component was 0.259 $Wm^{-2}K^{-1}$. The walls, made up of three types of material composition, had U values that varied from 0.193 $Wm^{-2}K^{-1}$ to 0.289 $Wm^{-2}K^{-1}$. The ceilings, of two different material compositions, had U values varying from 0.193 $Wm^{-2}K^{-1}$ to 0.356 $Wm^{-2}K^{-1}$.

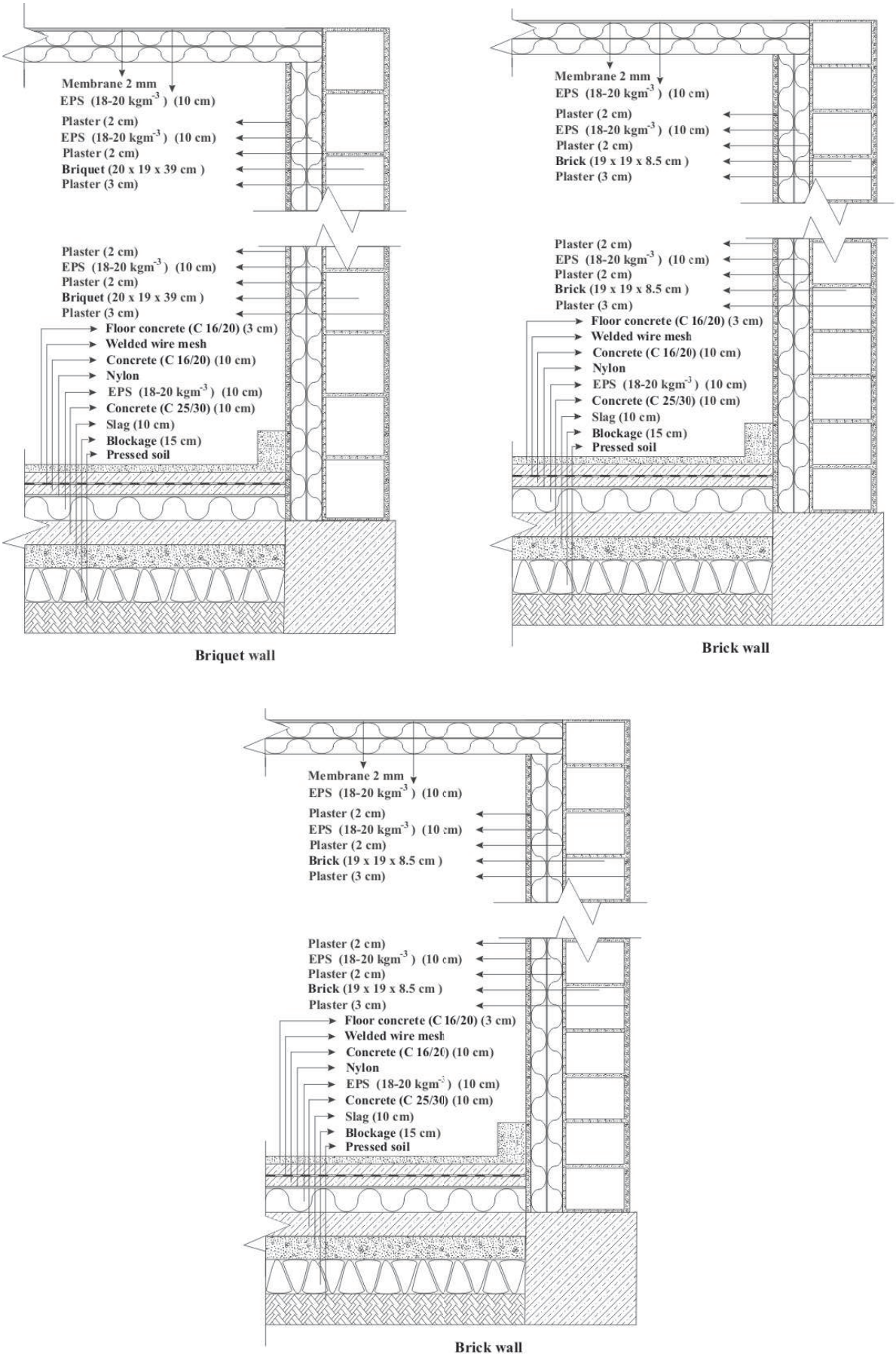

Figure 1. Details of briquette, brick and polyurethane sandwichpanel walls

Conclusions

Choices of materials used in the construction and isolation of cold storages for storing apples were different before 2000 and after 2000. After 2000, prefabricated concrete and steel were preferred for bring systems, rather than the conventional reinforced concrete that had been used previously. All the storage facilities used EPS as a flooring material. The walls of facilities constructed before 2000 used brick or briquette as a construction material and EPS for insulation; after 2000 the construction materials remained the same, but polyurethane panels were preferred for insulation. For ceilings, EPS has given way to polyurethane panels.

Before and after 2000, walls of cold storages were constructed from i) briquette, ii) brick, and iii) polyurethane sandwich panels, and ceilings were made from EPS or polyurethane sandwich panels. The use of these different construction and isolation materials over the years has given rise to three cold storage construction systems. Table 4 gives the total heat transfer coefficients of the floor, wall and ceiling components of these cold storage construction systems.

Total heat transfer coefficients for construction components in cold storage built before 2000 (construction systems 1 and 2) vary from 0.895 to 0.904 $Wm^{-2}K^{-1}$, and are higher than that of buildings constructed after 2000 (system 3), 0.645 $Wm^{-2}K^{-1}$. The change in choice of materials in recent years has caused a reduction in heat losses from building components of about 28%. This in turn has brought a large reduction in costs for the operators of these storage facilities.

Table 3. Heat transfer coefficients of the construction components

Construction components		Material	Thermal conductivity (λ) ($Wm^{-1}K^{-1}$)	Heat transfer coefficient (U) ($Wm^{-2}K^{-1}$)
Floor		Blockage	1.740	0.259
		Slag	0.130	
		Concrete	1.300	
		EPS	0.038	
		Nylon	0.230	
		Concrete	1.300	
		Floor concrete	1.300	
		λ_i	7.69	
		λ_o	25	
Wall	in used briquet	Plaster	0.870	0.280
		Briquette	0.290	
		Plaster	0.870	
		EPS	0.038	
		Plaster	0.870	
		λ_i	7.69	
		λ_o	25	
	in used brick	Plaster	0.870	0.289
		Brick	0.330	
		Plaster	0.870	
		EPS	0.038	
		Plaster	0.870	
		λ_i	7.69	
		λ_o	25	
	in used polyurethane sandwich panel	Polyurethane sandwich panel	0.020	0.193
		λ_i	7.69	
		λ_o	25	
Ceiling	in used polyurethane sandwich panel	Polyurethane sandwich panel	0.020	0.193
		λ_i	7.69	
		λ_o	25	
	in used EPS	Membrane	0.190	0.356
		EPS	0.038	
		λ_i	7.69	
		λ_o	25	

Table 4. Comparison of total heat transfer coefficients of three different kind of cold storage construction systems

Year of construction of the storages	Cold storage construction systems				Heat transfer coefficient (U) ($Wm^{-2}K^{-1}$)
	System No	Floor material	Wall material	Ceiling material	
Before 2000	1	EPS	Briquet	EPS	0.895
	2	EPS	Brick	EPS	0.904
After 2000	3	EPS	Polyurethane sandwich panel	Polyurethane sandwich panel	0.645

Nomenclature

d	materials thickness	m
U	heat transfer coefficient	$Wm^{-2}K^{-1}$

Greek letters

λ	thermal conductivity	$Wm^{-2}K^{-1}$

Subscripts

i	interior surface
o	outward surface

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