

A study of using solar energy to cure concrete bricks

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Abstract. Use of renewable energy sources such as solar energy, wind energy, tidal energy, etc. are important solutions in the trend for sustainable development. The purpose of this research is to build tunnels using solar energy to cure concrete bricks at saturated steam condition. Heat supply system and temperature monitoring of the tunnels consists of three main parts: solar thermal collector to heat water, heat trapping structure, and temperature measurement system with internet connection. The test operation of tunnels in industrial scale was conducted at a factory in Ho Chi Minh City. The results show that it can achieve temperatures above 50°C met curing requirements of concrete bricks. This can confirm the feasibility to use solar energy curing concrete bricks in plants with areas corresponding climatic conditions.

1. Introduction

Fired clay bricks are the traditional material used commonly in Vietnam. However, production of clay bricks requires consuming large amounts of clay and fuel that cause an adverse effect on the area of arable land and the environment. To solve this problem, in recent decades, Vietnam's Government has strengthened management in order to limit the production of clay bricks and develop unburned building materials. There are two important documents included the Decision-TTg dated 28/04/2010 567QD number of the Prime Minister on approving the *Development program unburned building materials by the year 2020* and Decision No. 1469 / QD-TTg of the Prime Minister: *To approve the master plan on development of Vietnam's construction materials up to 2020 and orientations to 2030*. Accordingly, by the year 2020, Vietnam needs about 30 billion standard bricks. The amount of unburned materials will account for about 40% respectively 12 billion standard bricks, in which concrete bricks account for 70% of unburned materials.

In the production process of concrete bricks, steam curing stage is needed to develop strength fast, stable quality and shorten manufacturing process. According to many studies, temperatures of the curing is 50 to 100°C [1] and it need about 9- 18 h in a condition of saturated steam curing to reach 70% of compressive strength at age of 28 days [2]. Steam supply source for the curing process is typically from boilers fired by fossil fuels. Disadvantages of boilers is demanding fuel costs, labour safety and environmental impact. To overcome this drawback, there have been studies using solar energy for curing process

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with high efficiency. Podgornov N.I. [1] mentioned that curing temperature is higher 30°C than ambient temperature when using the structural solar collectors as shown on Fig. 1. After 3 days cured in tunnels using solar energy, compressive strength of concrete reach 70-80%, and after 5-7 days' reach 100% that of the design strength.

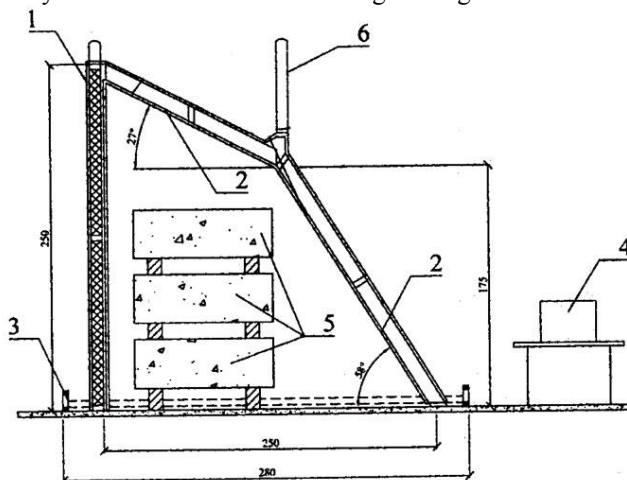


Fig. 1. Structure collecting solar energy to cure concrete structures
 1- insulating wall; 2- , heat **trapping structure**; 3-water trough;
 2- 4- control device; 5- concrete structures; 6- structure used when assembling.

A construction company in Qashqadaryo, Uzbekistan built curing tunnels in industrial scale collected solar energy. Concrete floors and walls of the tunnels with heat accumulating function from the sun's rays; and the roof of the tunnel with 30° angle compared to the horizontal were made of two-glass layers with 30mm of space between them. When the ambient temperature is $35\text{--}40^{\circ}\text{C}$, temperature in the tunnels reaches $70\text{--}80^{\circ}\text{C}$. After cured 1 day, concrete structures achieve 45-50%, and after 2 days of reaching 60-70% compressive strength of design. In Pennsylvania, the United States, several factories have used steam at a temperature of 180°C heated by solar energy to cure concrete structures. Thermal energy savings is up to 35% annually [1].

The Southern Vietnam is located in the area of tropical monsoons climate with high temperatures and rainy-dry seasons. Annual statistics [3] have shown that the average temperature in the Southern region is around 28.8°C , the highest compared to that of the country. Temperatures between the months of the year is also very stable with high thermal radiation $5595 \text{ W/m}^2/\text{day}$, and sunshine hours are 207h/ month. This is a good condition to be able to take advantage of solar energy for the curing process.

Currently, in Vietnam concrete brick factories has not really pay attention in the curing process. Each plant uses different curing processes such as wet spraying on 1-2 days, soaking in water, saturated steam maintenance with steam generated from boilers, etc. This is a cause of amount increases of used cement, unstable quality of products and large store area. Therefore, the purpose of this study is using solar energy to cure concrete bricks and apply in the Southern region of Vietnam. Based on the result of this research, applications of solar energy could be strengthened to implement that allow reduced fuel costs and CO_2 emissions.

2. Materials and Methods

This study was implemented in Dai Dung green materials joint stock company in Hiep Phuoc Industrial Zone, Hiep Phuoc, Nha Be District, Ho Chi Minh City. Concrete bricks with 4 round holes and dimension of 80x80x180 mm were used for tests. Mixture compositions to produce bricks are PC40 cement 200 kg/m³, aggregate 1700 kg/m³, fly ash 60 kg/m³, and water 250 l/m³. Test method TCVN 6477: 2016 was use to determine the compressive strength of the two groups: samples 1 were cured in tunnels using solar energy, samples 2 were stored in indoor condition. The aim of tests is to determine influence of maintenance conditions on development of compressive strength.

Production process of concrete bricks using solar energy is basically the same the normal process from preparing to shaping steps. After being shaped, bricks are lined up racks, next kept in 10-12 hours in curing tunnels to reach strength of packaging, then wrapped plastic film up, and lastly stored in 10-14 days. The process of manufacturing concrete bricks is described in Fig. 2.

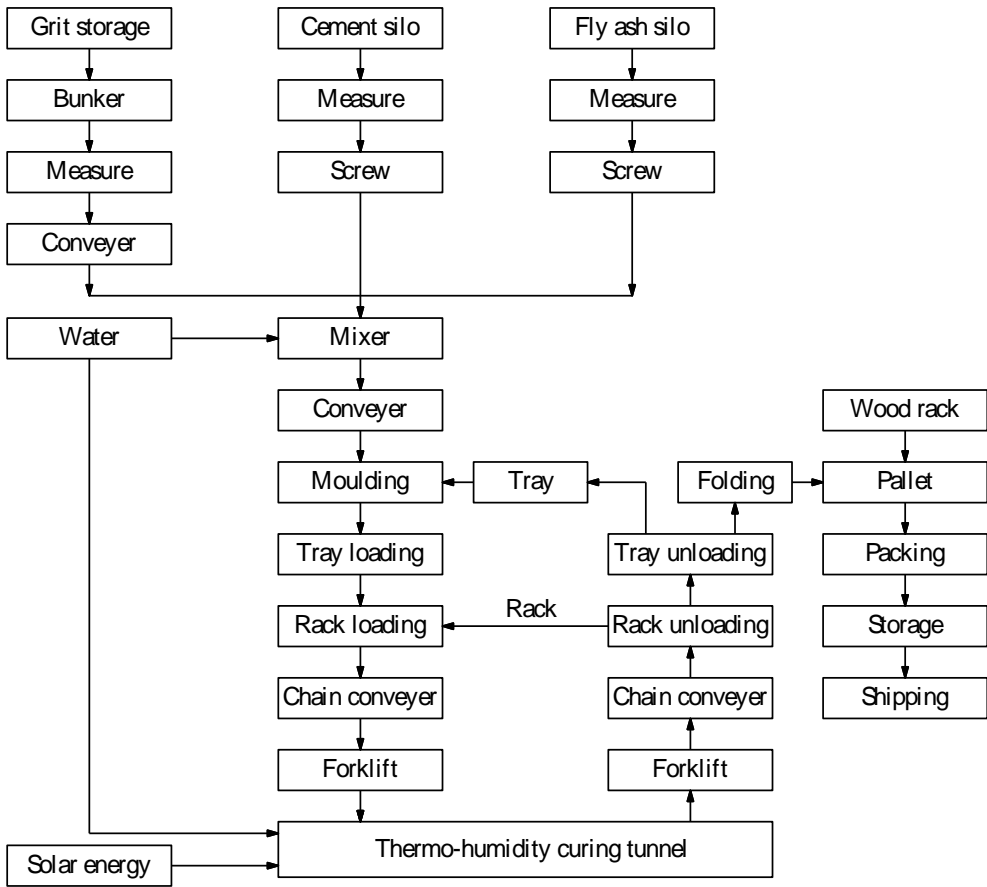


Fig. 2 Diagram of the line production technology of concrete bricks

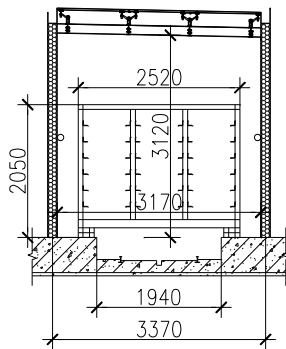


Fig. 3 Cross section of curing tunnel

After shaping, bricks were moved to the system of 7 curing tunnels using solar energy. The size of each tunnel is length $L=24\text{ m}$, width $W=3.17\text{ m}$ and height $H=3.12\text{ m}$. The bottom of the tunnel is made from reinforced concrete with 0.25 m of thick, the walls is made from 100 mm thick layer of styrol concrete. The roof of the tunnel is made of two plates of tempered glass receiving sunlight, that is so called heat trapping structure to provide heat for the curing process (see Fig. 3).

Heat supply system and temperature monitoring of tunnels includes 3 main parts as following:

2.1 Solar thermal collector

Solar thermal collector of MGS VC-1850 heating water includes 10 panels with 500 kg/panels . Each panel is composed of two successive smaller plate with dimensions of $2000\times4000\text{ mm}$ including 50 pipes of size $58\times1800\text{ mm}$. The panels are fixed to the roof of the factory. Cold water is supplied to the solar collector plates by a pipe with diameter of 50 mm . Hot water goes out to a tank by a pipe with increased diameter of 32 mm , 40 mm , and 50 mm (see Fig.4).

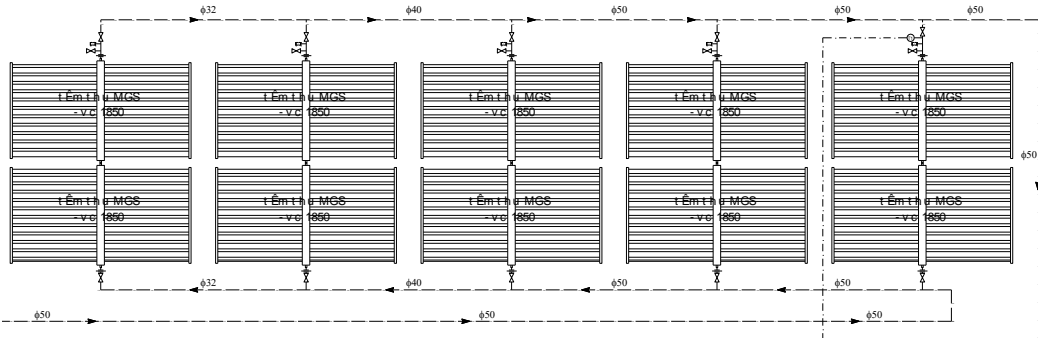


Fig. 4. Layout of solar panels heating water

2.2 Heat trapping structure

Heat trapping structure is made from 2 tempered glass plates with the distance between them is $20\text{-}25\text{ mm}$. The plates are sealed together with glue to make sure no air or moisture enters. The inclination of glass roofs is minimum of 2% that make rainwater and steam can not be deposited on the surface of glass. The gap between the two glass plates have the

effect of retaining the energy reflecting back to the environment, therefore they are called heat trapping structure

2.3 Temperature measurement system

8 temperature sensors are installed for each curing tunnel in which the sensor #1 measure temperature of heat water at sprinkler head spraying water, another one is used for waste water, 5 sensors show internal temperature of a tunnel and a sensor shows ambient temperature. Only with tunnel number 7, an outside sensor (# 8) is used for measuring the hot water temperature in a tank. The signal of all these sensors are transmitted from a transceiver to a GPS system. Then, the data is shown on the monitor via the internet. Thus, we can check temperature anywhere and at any time. The temperature measurement system using the type of DS18B20 sensors with error less than 0.5 ° C, and measure range of -55°C to +125°C.

3. Results and Discussion

3.1 Temperature measurement results in the curing tunnels [4]

Temperature measurement results on a monitor could be get as shown in Fig. 5.

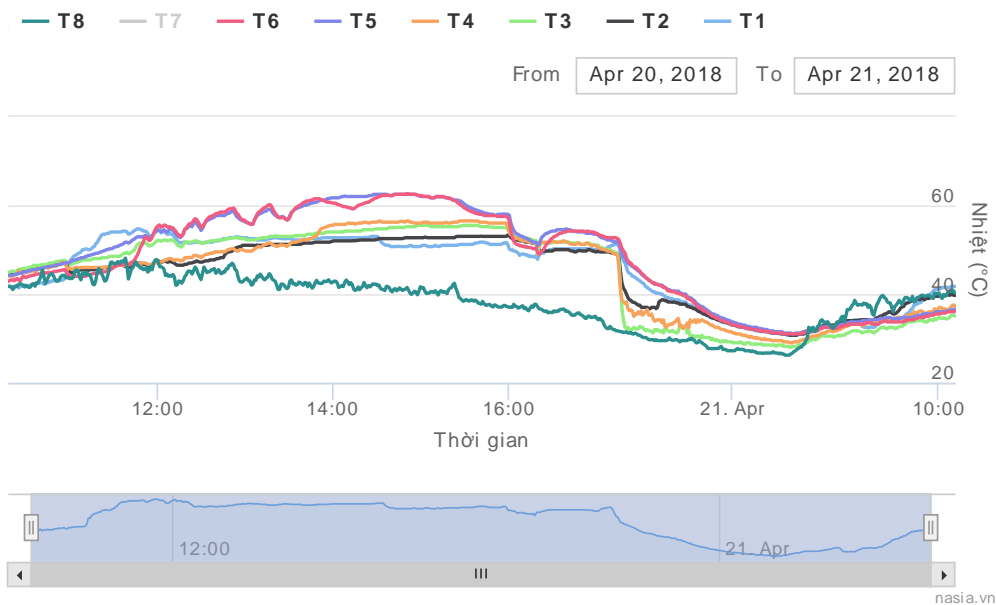


Fig 5. Temperature chart of the tunnel #7 on April 20, 2018

The tunnels should continuous work with the entire production process of the factory. Therefore a operation plan of the 7 tunnels was designed as Table 1.

Table 1. An operated plan of the 7 curing tunnels on a day

Num ber of tunn el	Time of a day																							
	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20	21	22	23	24
1					E		A			B														
						E	A			B														
2							E	A		B														
							E	A		B														
3									E	A														
									E	A														
4										E	A													
										E	A													
5															A			B						
															A			B						
6															E	A			B					
															E	A			B					
7																		E	A					
																		E	A					

Notation : A- Time to supply brick racks to a tunnel, 2 h;
 B- Time to stabilize bricks, 4 h;
 C- Time to cure bricks a tunnel, 8 h;
 D- Time of tempering and cooling bricks in tunnels, 8 h;
 E- Time of unloading bricks out of a tunnel, 2 h;

The research team has conducted a test operation of the curing system using solar energy, and measured and analysed temperature data from June 5, 2018 to July 4, 2018 in the tunnels of over 50°C. Temperature measurement results are listed in Table 2.

Table 2. Temperature measurement results in the 7 tunnels (°C)

Date	Number of tunnels						
	1	2	3	4	5	6	7
June 5						52.6	
June 6	50.2			51.5		52.6	
June 7			55.8	57.5	59.5		
June 8			50.1	50.9			
June 9		52.8	53.0				
June 10		56.6	57.1				53.6
June 11		51.4	53.5				
June 12		53.6					
June 13							
June 14			52.9				
June 15			52.1	54.0			
June 16					52.8	54.4	
June 17						52.8	
June 18					50.6		
June 19	50.1	50.1			52.7		
June 20						57.4	

June 21		51.1			52.7	56.5	
June 22							
June 23			50.2			58.1	
June 24		51.3			53.4	52.1	50.0
June 25						54.4	
June 26		50.1		50.5		57.1	
June 27		51.7	55.2	55.1			
June 28	55.3	60.5	58.5				
June 29	57.4	56.2	53.6		55.8	50.3	
June 30					57.6	57.2	51.2
July 1				55.3	60.6		51.6
July 2							
July 3		53.7	51.7	52.7			
July 4	52.3		50.8	52.1	53.2	54.6	
Sum	5	12	13	9	10	13	4

Temperature in curing tunnels was over 50°C in 26 days of the month trial operating. Averagely temperature of 2.54 tunnels was over 50°C per day, so the rate was 86.7% compared with sunny days. Because of trial operation, brick forming system did not work stably, therefore there were not many brick in the tunnels. That means heat of hydration of cement had not been taking full advantage, causing decrease of maximum temperature. The temperature is expectably higher when the entire production system of the factory stabilizes.

3.2 Effect of curing regime on the development of brick strength

To compare the effect of curing regime on the development of brick strength, brick samples were divided into 2 groups, namely: group 1 samples were taken at different position of brick racks, next cured in tunnels in 1 day, then stored in a room condition; immediately after forming, group 2 samples were covered/ not covered by plastic film, then stored in room condition. Results of compressive strength test are given in Table 3.

Table 3. Compressive strength of concrete brick samples

Curing condition			Compressive strength of concrete brick samples, MPa/%				
	Number of tunnel	Position of bricks	$f_c^{1\text{ day}}$	$f_c^{3\text{ days}}$	$f_c^{7\text{ days}}$	$f_c^{14\text{ days}}$	$f_c^{28\text{ days}}$
Curing in tunnels	Sô 2	Side	5.83/40.5	7.59/52.7	12.70/88.2	13.15/91.3	14.4/100
		Center	5.16/34.6	7.06/47.3	11.62/77.9	14.10/94.6	14.9/100
		Top	5.24/50.3	6.83/65.6	6.92/66.5	8.26/79.4	10.4/100
	Sô 3	Side	4.79/42.3	6.60/58.4	7.56/66.9	10.60/93.8	11.3/100
		Center	5.25/44.1	7.33/61.6	9.0/75.6	10.50/88.2	11.9/100
		Top	5.07/43.2	7.10/60.5	7.4/63.9	8.50/72.4	11.7/100
Store in room	Not covered		3.23/28.8	4.74/42.3	-	-	11.2/100
	Covered		3.44/26.8	5.26/41.1	-	-	12.8/100

Note: data are presented in the form of fractions A/B in which A is compressive strength at respective age (MPa), B is the compressive strength ratio between the age and B is the ratio of compressive strength at age respectively compared to 28 days (%)

The results in Table 3 show that there is the difference in the development of compressive strength. However, strength of group 1 samples after 1-day cured in the tunnels was averagely 42.5% compared to that at 28 days; strength of group 2 samples was 27.7% respectively.

3.3 Evaluate the effectiveness of energy, environment and investment

According to calculations, curing by solar energy will shorten the time taken to use the concrete bricks as shown in Table 4. Moreover, the number of pallets is reduced to 1/3, area storing products lessen 30-40%.

Table 4. Calculating effect on time of curing by solar energy

	Curing by using solar energy	Moist curing
Time to exworks	3-5 days	21 days
Time to use	10-14 days	28 days

Based on operation results of the 7 tunnels, fuel cost for curing was calculated when reaching design capacity of 37 million standard bricks/ year of a production chain. Namely, 5.3 ton of coal or 3.2 ton of FO oil is need for curing by boilers. Investment costs for the entire curing system would be 2.4 billion VND. As a result, it is needed 4 years for capital recovery. Furthermore, the use of solar energy for curing would cut CO₂ emissions by 2.2 million m³/ year and 1.7 million m³/ year in cases of coal and FO oil respectively.

4. Conclusions

Based on the results of installing, operating and measuring temperature the curing tunnels using solar energy in Dai Dung green materials joint stock company, some conclusions could be drawn as following:

- Solution of using solar energy to cure concrete brick in the Southern region is workable with the rate of the highest temperature reaching above 50°C is 86.7%.
- Curing by using solar energy promotes development of concrete brick strength. Namely after 1-day curing, compressive strength of brick samples achieved 42.5% of that at 28 days higher than that of the control sample at 27.7% respectively.
- At capacity of 37 million standard bricks/ year, curing by using solar energy saves 5.3 ton of coal or 3.2 ton of FO oil and cut CO₂ emissions by 2.2 million m³/ year and 1.7 million m³/ year respectively compared to curing by boilers.

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