SHORT REPORT

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CALCULATIONS OF FIXED OPTIMUM TILT ANGLES FOR FLAT-PLATE SOLAR COLLECTORS FOR SONGKHLA, BANGKOK, KHON KAEN, AND CHIANG MAI

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Abstract

Fixed optimum tilt angles for flat - plate solar collectors for four cities in Thailand have been calculated: Songkhla (4.2), Bangkok (10.0), Khon Kaen (11.9), and Chiang Mai (13.5). The relationship between latitudes (L) and fixed optimum tile angles (To is represented approximately be a linear equation : $T_o = 0.79L - 1.14$.

At present, there area large number of flat-plate collectors installed in Thailand for producing domestic hot water and hotel hot water supplies. One problem found in installation is that engineers do not know what tilt angle is suitable for each area. In practice, they use the value of latitude as the value of fixed tilt angle for each area, which is incorrect. This paper gives a way of finding the correct angle for various locations in Thailand.

The simple simulation model[1] is composed essentially of seven basic equations:

$$\cos\theta = \cos(L)\cos(d)\cos(h) + \sin(L)\sin(d) \quad (1)$$

$$\cos\theta_T = \cos(L-T)\cos(d)\cos(h) + \sin(L-T)\sin(d) \quad (2)$$

$$\bar{H}_d = \bar{I}_d + \bar{D}_d \quad (3)$$

$$\bar{I}_T = \bar{I}_d \cdot \cos(\theta_T)/\cos(\theta) \quad (4)$$

$$\bar{D}_T = \tfrac{1}{2}\,\bar{D}_d\,(1+\cos(T)) \quad (5)$$

$$\bar{H}_T = \bar{I}_T + \bar{D}_T \quad (6)$$

and

$$\Sigma\bar{H}_T = \bar{H}_{T1} + \bar{H}_{T2} + \cdots + \bar{H}_{Tn_p} \quad (7)$$

where θ is the angle between the line to the sun and the vertical

$\bar{H}_{T1}$ is the angle between the line to the sun and the normal to the titled surface

L is the latitude

d is the angle of solar declination

h is the hour angle

T is the tilt angle of a tilted surface facing the south

$\bar{H}_d$ is the mean daily total of global solar radiation falling on a horizontal surface for diffuse rays

$\bar{T}_d$ is the mean daily total of direct solar radiation falling on a horizontal surface for diffuse rays

$\bar{D}_d$ is the mean daily total of diffuse solar radiation falling on a horizontal surface for diffuse rays

$\bar{T}_T$ is the mean daily total of direct solar radiation falling on a tilted surface under actual weather conditions

$\bar{D}_T$ is the mean dialy total of diffuse solar radiation falling on a tilted surface from a uniformly bright sky

$\bar{H}_T$ is the mean daily total of global solar radiation falling on a tilted surface under actual weather conditions

$\Sigma\bar{H}_T$ is the summation of $\bar{H}_T$ at any T for all seasonal periods (n_p)

n_p ranges from 1-8.

From the results obtained, it is possible to find the maximum value for $\Sigma\bar{H}_T$. Therefore, the value of T for the maximum $\bar{H}_T$ is called the fixed optimum tilt angle (To) for flat-plate collectors facing south for the whole year in the area considered.

According to the conditions, the value of h considered at solar noon is zero, $\bar{D}_d$ is 8.4 MJ/m^2 for Thailand[2], T is varied from 0° to 20° at 0.1° intervals for each calculation used in those equations by using a microcomputer, and the other data for each city can be derived from Exell's data[2]. The data used in the model above are shown in Table 1.

TABLE 1. DATA FOR MEAN DAILY TOTAL OF GLOBAL SOLAR RADIATION OF FOUR CITIES IN THAILAND (FROM REF 2).

Conditions			Songkhla	Bangkok	Khon Kaen	Chiang Mai
Dates	n_p	Mean d(°)	$\bar{H}_d$(MJ/m^2)	$\bar{H}_d$(MJ/m^2)	$\bar{H}_d$(MJ/m^2)	$\bar{H}_d$(MJ/m^2)
14 Jan – 26 Feb	1	−15.83	18.074	16.827	16.778	17.238
27 Feb – 12 Apr	2	0	19.340	19.437	18.165	19.345
13 Apr – 28 May	3	15.83	18.186	18.296	19.527	20.225
29 May – 15 Jul	4	22.78	16.570	16.585	17.485	17.327
16 Jul – 31 Aug	5	15.83	16.990	15.418	16.412	15.693
1 Sep – 15 Oct	6	0	15.988	15.030	16.498	17.253
16 Oct – 29 Nov	7	−15.83	14.654	16.327	17.554	16.973
30 Nov – 13 Jan	8	−22.78	14.888	16.690	16.452	15.509

The values of the fixed optimum tilt angle obtained for four cities in Thailand are shown in Table 2.

TABLE 2. LATITUDES (L) AND FIXED OPTIMUM TILT ANGLES TO AT VARIOUS LOCATIONS IN THAILAND

CITY	L (°N)	T_o (°)
Songkhla	6.92	4.2
Bangkok	13.73	10.0
Khon Kaen	16.43	11.9
Chiang Mai	18.78	13.5

The relation between L and To is found to be a straight line with T_o = 0.791 - 1.14 (r = 0.998), see Fig. 1. This line should be of use for determining fixed optimum tilt angle from any latitude in Thailand.

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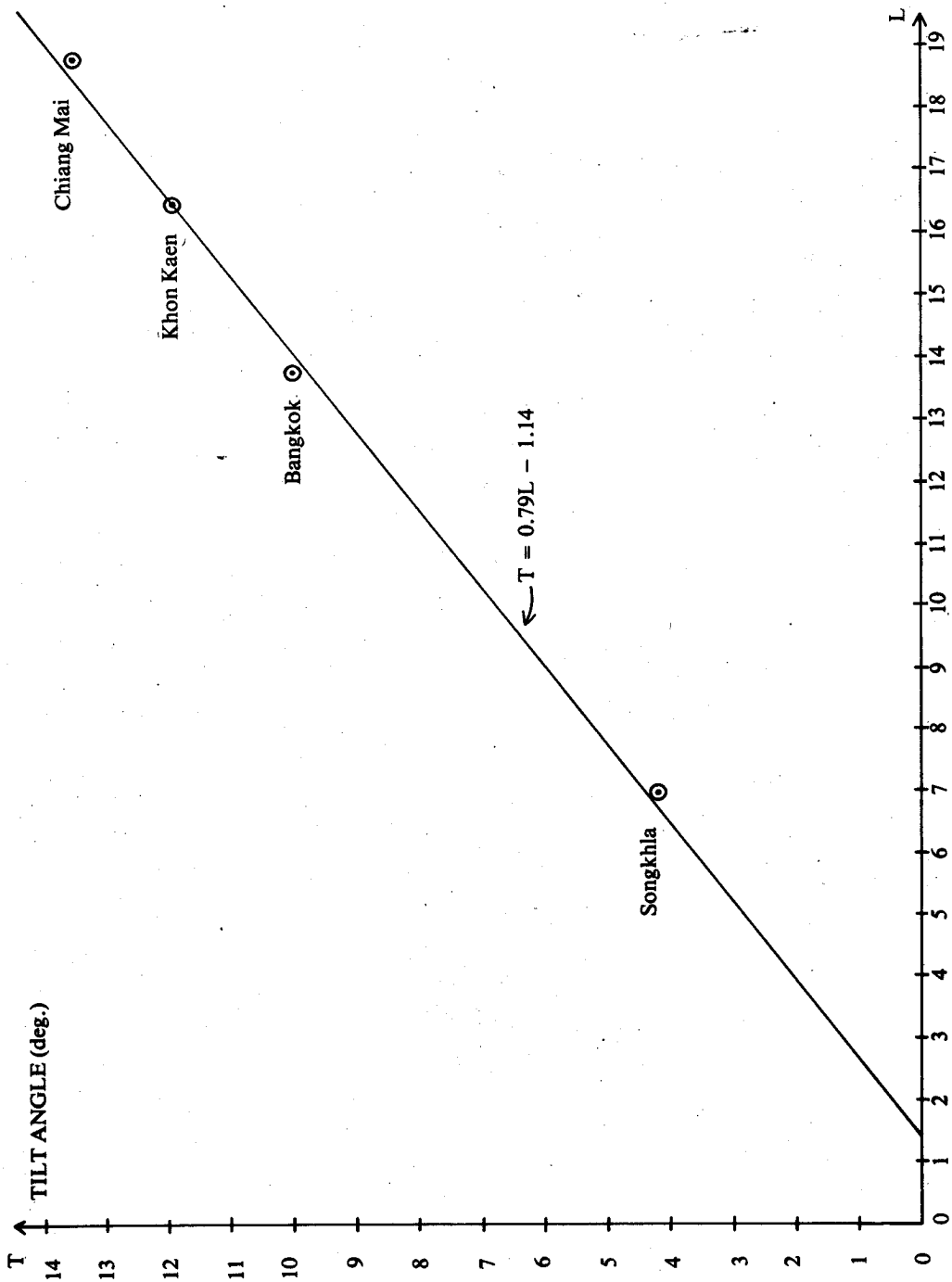

Figure 1. Variation of fixed optimum tilt angle at different latitudes in Thailand.

References

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2. Exell, R.H.B. (1980) Simulation of Solar Radiation in a Tropical Climate with Data for Thailand. AIT Research Report No. 115, Renewable Energy Resources Information Center, AIT, Bangkok.

บทคัดย่อ

มุมเอียงคงที่ที่เหมาะสมที่จังหวัดสงขลามีค่า 4.2 องศา ที่จังหวัดกรุงเทพฯ มีค่า 10.0 องศา ที่จังหวัดขอนแก่นมีค่า 11.9 องศา และที่จังหวัดเชียงใหม่มีค่า 13.5 องศา นอกจากนี้ยังได้กราฟที่สร้างขึ้นจากความสัมพันธ์ระหว่างค่าละติจูดกับค่ามุมเอียงคงที่ที่เหมาะสมเป็นเส้นตรงซึ่งสอดคล้องกับสมการเส้นตรง $T_o = 0.791 - 1.14$