Chapter IV

Results and Discussions

The experimental results obtained in this study may be summarized as follows.

Water Retention of Sand with and without Water Absorbing Polymers.

The water holding capacity of the type of sand used in this study with and without the presence of Water Absorbing Polymers (WAP) was the very first piece of information that was needed at the start of this work. Three concentrations of WAP in sand were used : 0.2%, 0.4%, and 0.5% of dry WAP to ambient sand by weight. The ambient sand used was measured to contain about 3% moisture.

The type of sand used in this study when saturated with water yielded a water content of about 60 percent weight of the total dry weight of ambient sand (see appendix A-1). When 0.2 weight percent of WAP was mixed in the sand it was also found that the water content of the mixture was again in the neighborhood of 60 percent weight of dry sand mixed with WAP weight (see appendix A-2). When 0.4 weight percent of WAP was added to the sand the water content increased to about 103 percent of initial ambient sand weight (see appendix A-3). When 0.5 weight percent of WAP was added to the sand the water content increased to about 120 percent of initial ambient sand weight (see appendix A-4). As expected WAP containing sand has a greater water loading factor than sand only.

This water contained in the sand mixture can be allocated into three components, the free water in the open pores of the packed bed, the water retained by the sand, and the water absorbed by the water absorbing polymers. In this work it was decided to study the evaporation of water into a controlled atmosphere without distinguishing how the water was being trapped in the packed bed. A case could be made for doing the same study without the free water which would have meant draining all free flowing water out of each column prior to each experiment. However it was decided in this study to perform each experiment with all the free volumns in the packed bed full of water because it was easy to control the initial condition to be the same conditions.

As evaporation occurs the WAP containing sand retains water over a longer period of time. Figure 4.1 compared the surface water content of a WAP-free sand column against a WAP-containing sand column.The figure basically shows that after some 8 hours of evaporation under an atmosphere containing 25% RH and an ambient temperature of 50 degree Celcius, the sand only

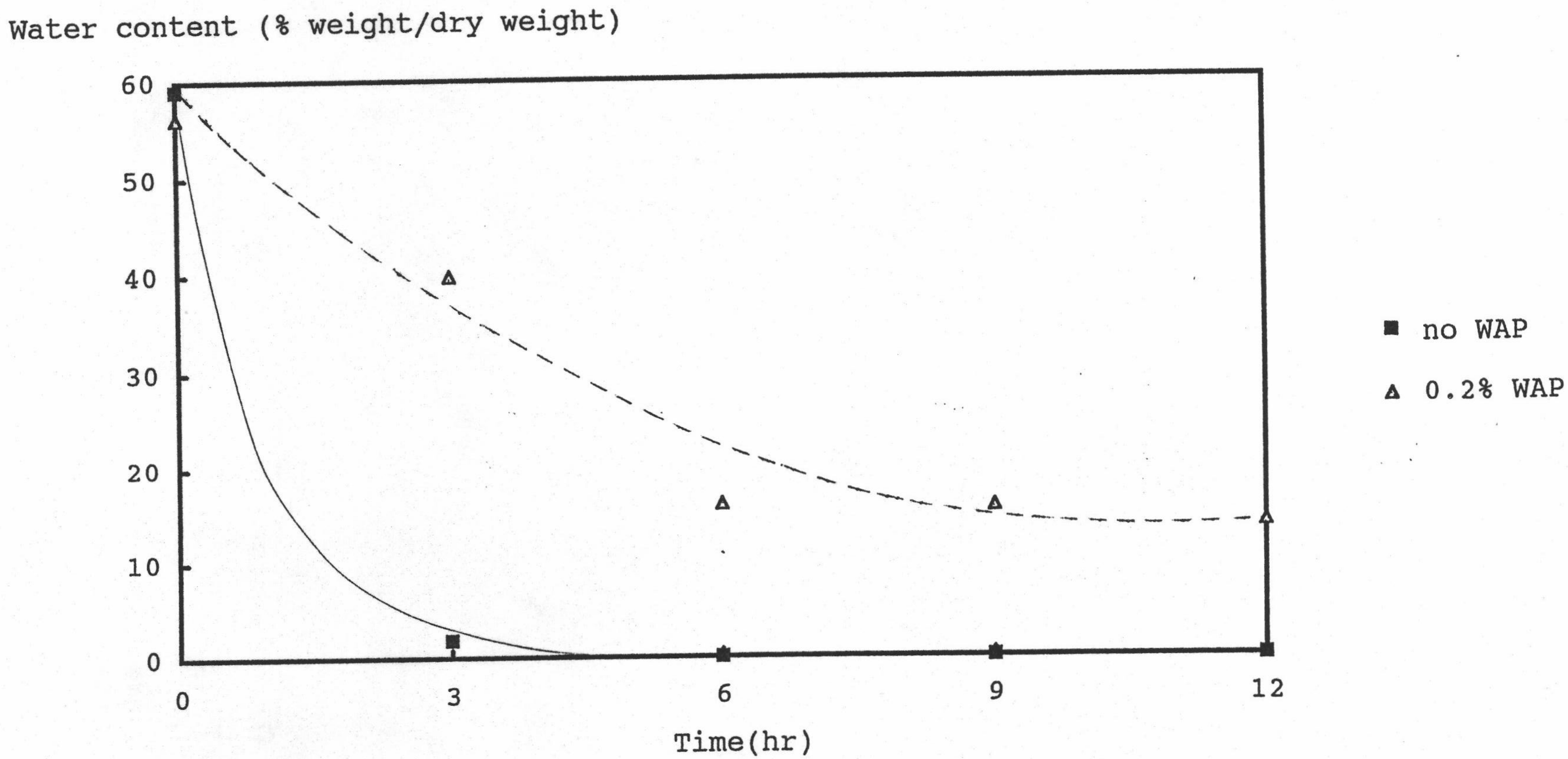

Fig.4.1 The surface water content of WAP-free sand column compares with sand column containing 0.2% WAP by weight using ambient air conditions : 50 degree Celcius, 25% RH

experiment indicates an almost dry bed surface whereas the bed surface of the WAP containing sand still contains substantial amount of water after 12 hours.

results of evaporation experiments

Evaporation experiments were conducted for sand columns containing the following concentrations of WAP in weight percent : 0%, 0.2%, 0.4%, 0.5%. The ambient humidities used were 25%RH and 40%RH, an ambient temperatures used were 30, 40, 50 degree Celcius.

1 Experimental data of 0% WAP

Six sets of evaporation experiments were made on WAP-free sand columns as shown on figures 4.2(a) to 4.2(f) for the following respective ambient air conditions as shown in Table 4.1.(Lines in these figures are the only visual guide lines which are no meaning in the mathematics model.) The data is presented in appendix A-5 to A-10. The initial water contents were about 60 percent weight/dry weight but only a few hours water contents at the surface of sand columns decreased to nearly 4 percent but the water contents at the bottom of the columns still retained about the same initial contents. After 6 hours of experiments water contents at the surface of the columns decreased to nearly 0% and water contents at the bottom decreased to about half of initial water contents. At the ending of the experiments, there were no water left at the surfaces while were a little at the bottoms.

Table 4.1 Six sets of evaporation experiments on measuring water contents of sand columns.

Temperature	Relative humidity
30 degree Celcius	25% RH
	40% RH
40 degree Celcius	25% RH
	40% RH
50 degree Celcius	25% RH
	40% RH

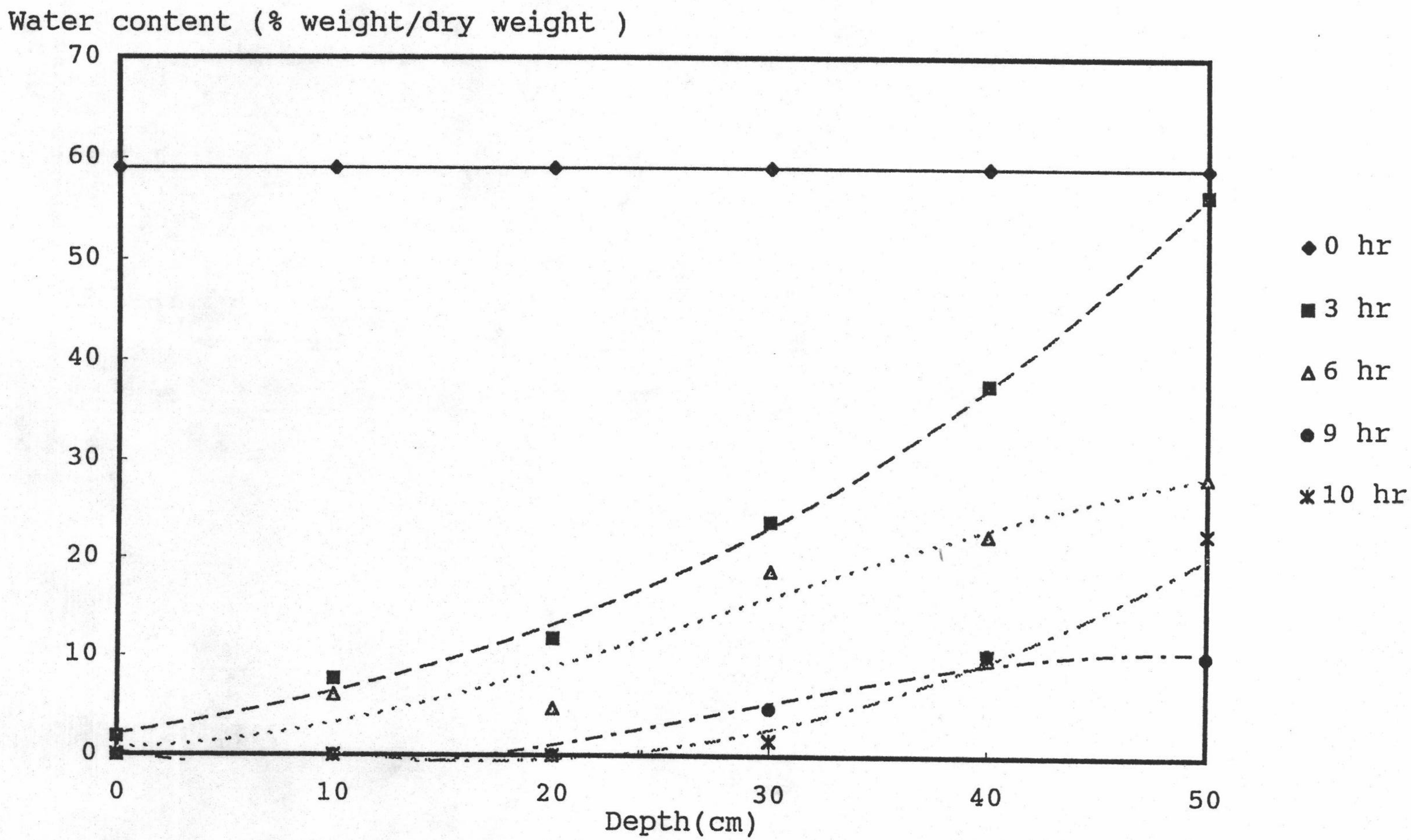

Fig. 4.2 (a) Water content of WAP-free sand column using ambient air conditions : 50 degree Celcius, 25% RH

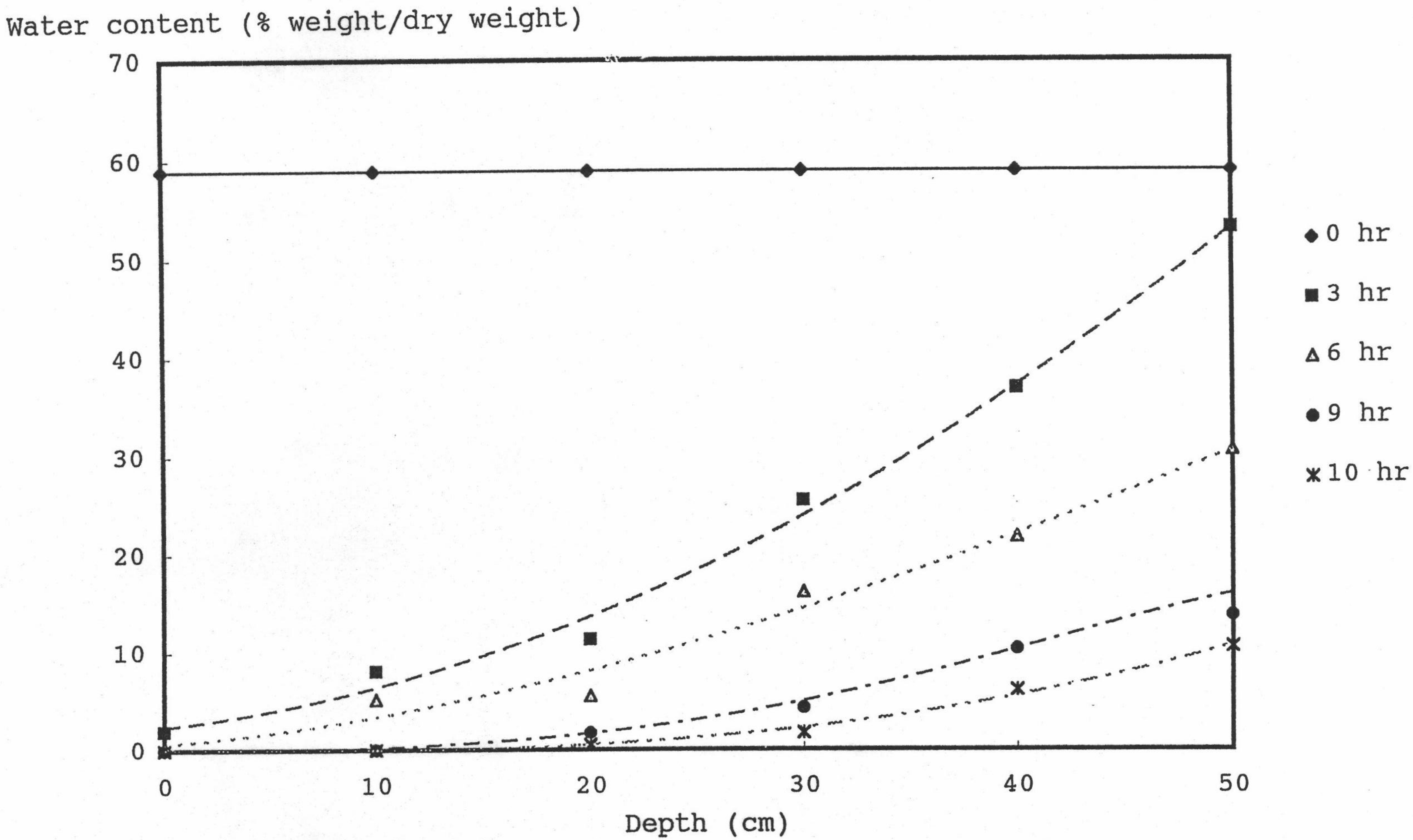

Fig. 4.2 (b) Water content of WAP-free sand column using ambient air conditions : 50 degree Celcius, 40% RH

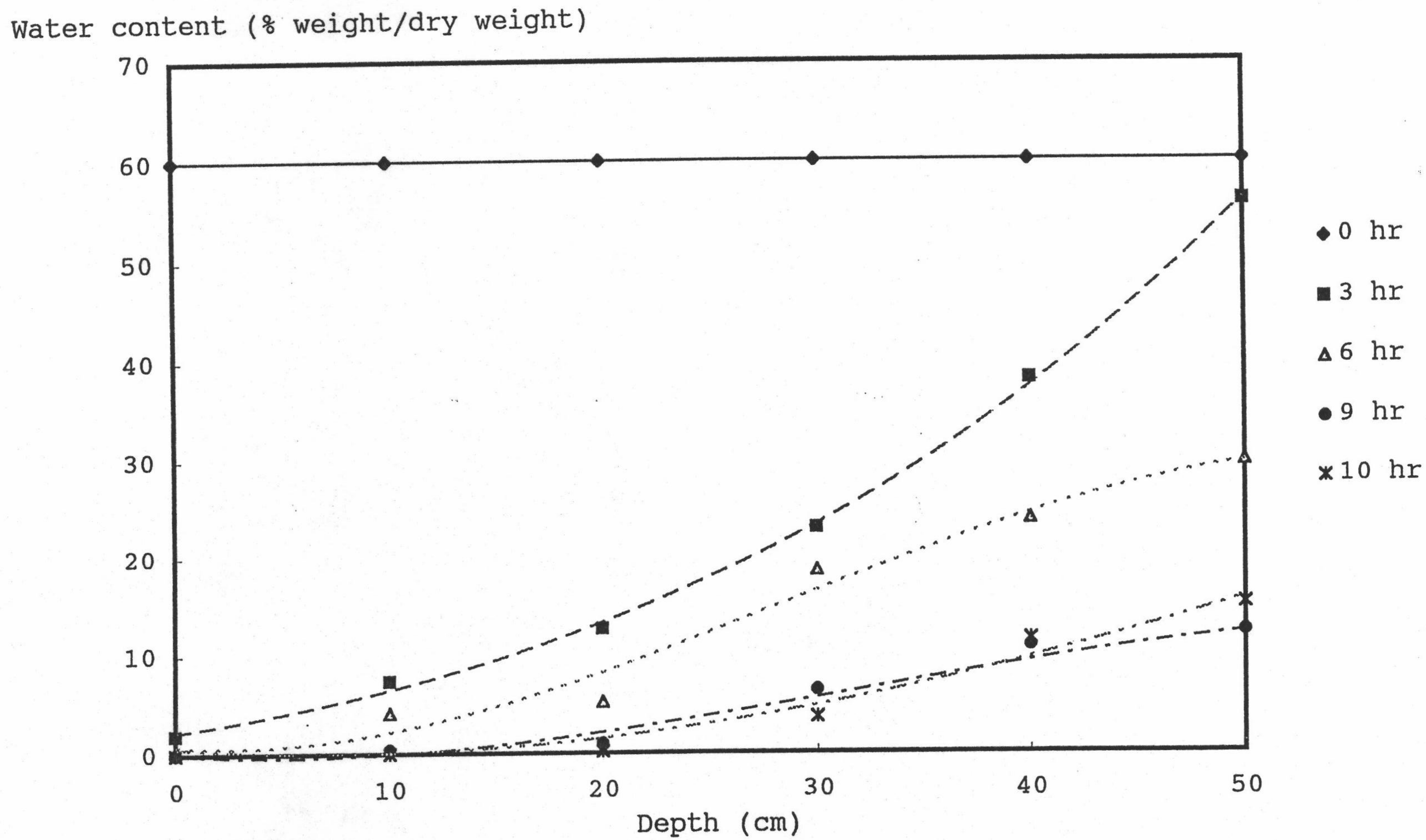

Fig. 4.2 (c) Water content of WAP-free sand column using ambient air conditions : 40 degree Celcius, 25% RH

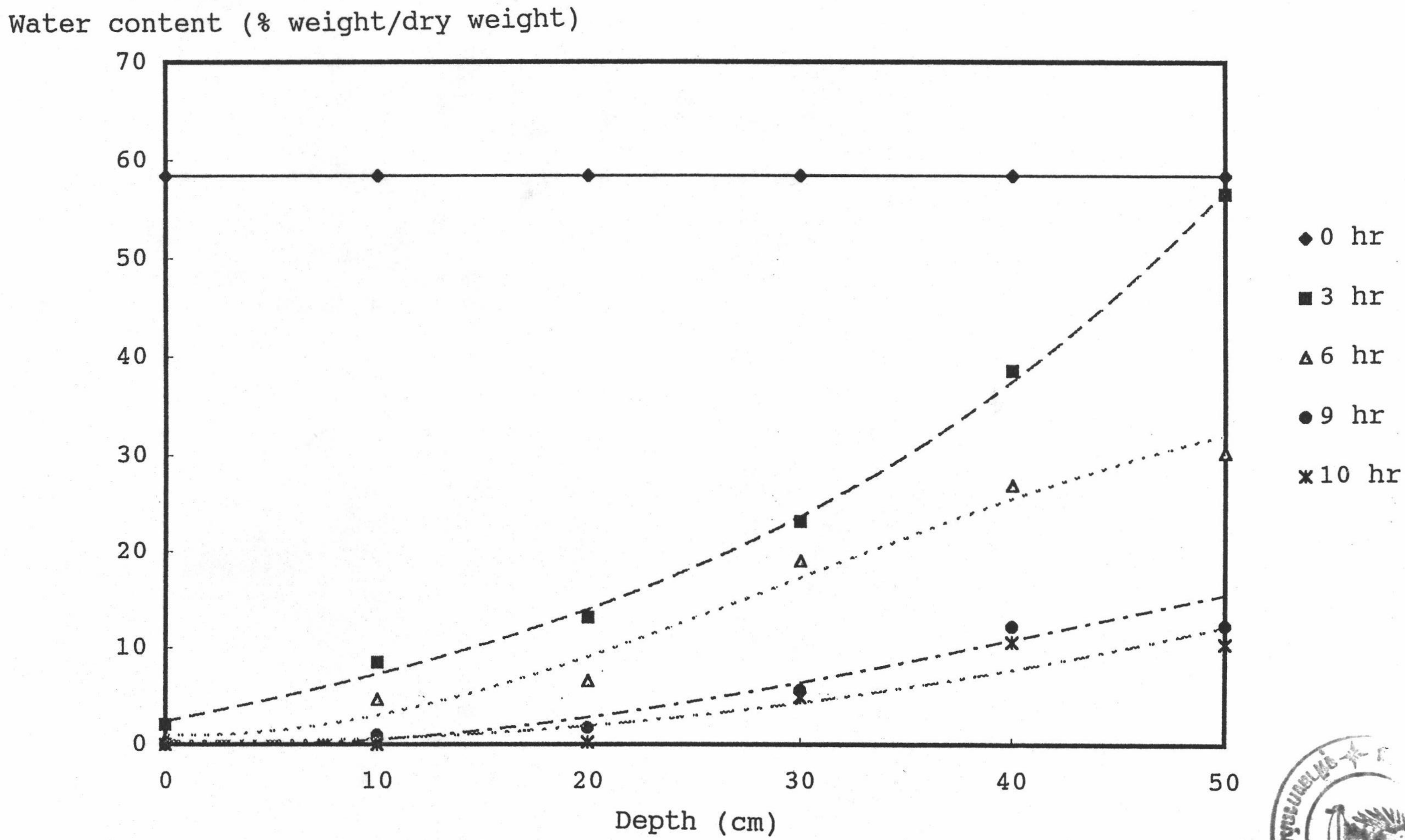

Fig. 4.2 (d) Water content of WAP-free sand column using ambient air conditions : 40 degree Celcius, 40% RH

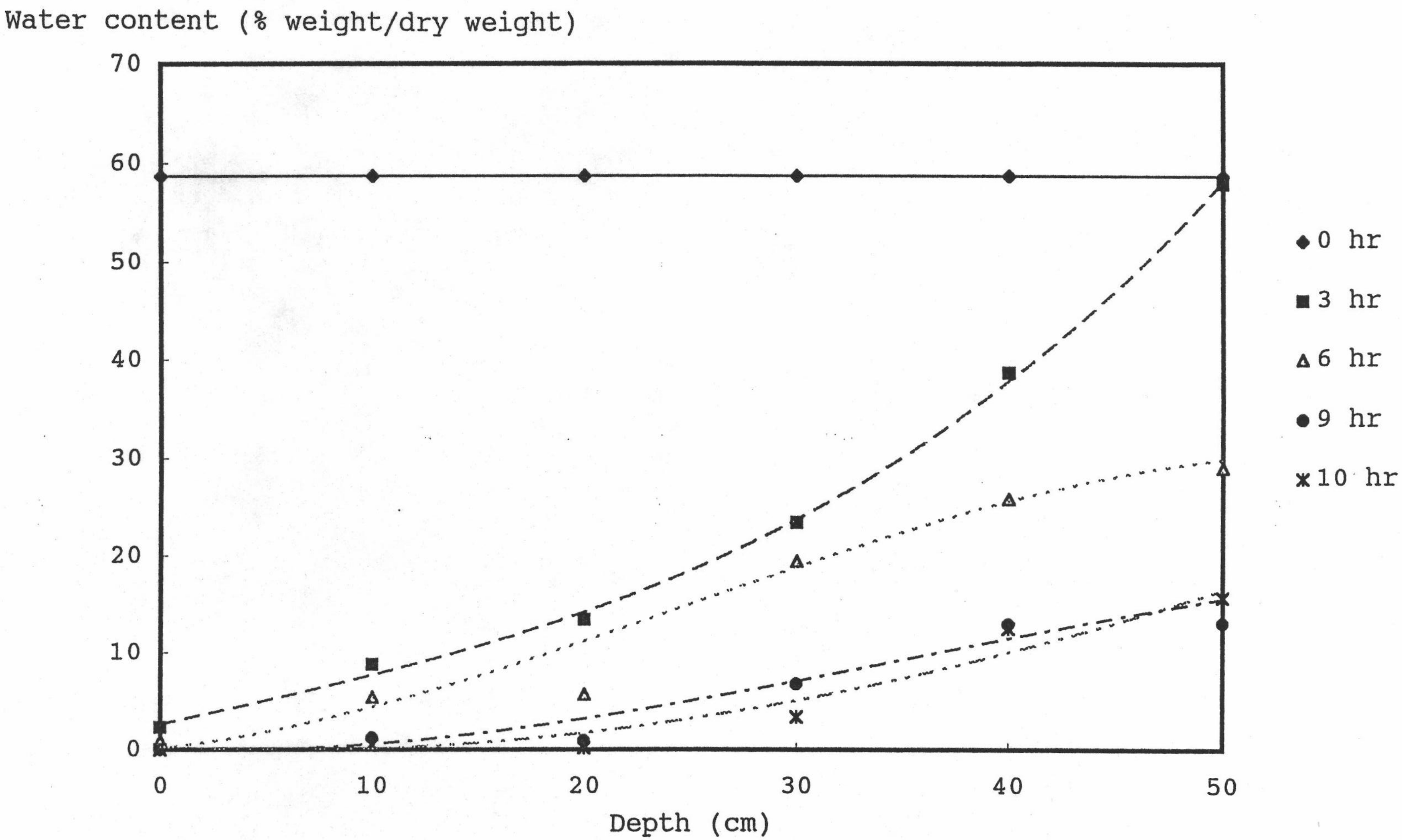

Fig. 4.2 (e) Water content of WAP-free sand column using ambient air conditions : 30 degree Celcius, 25% RH

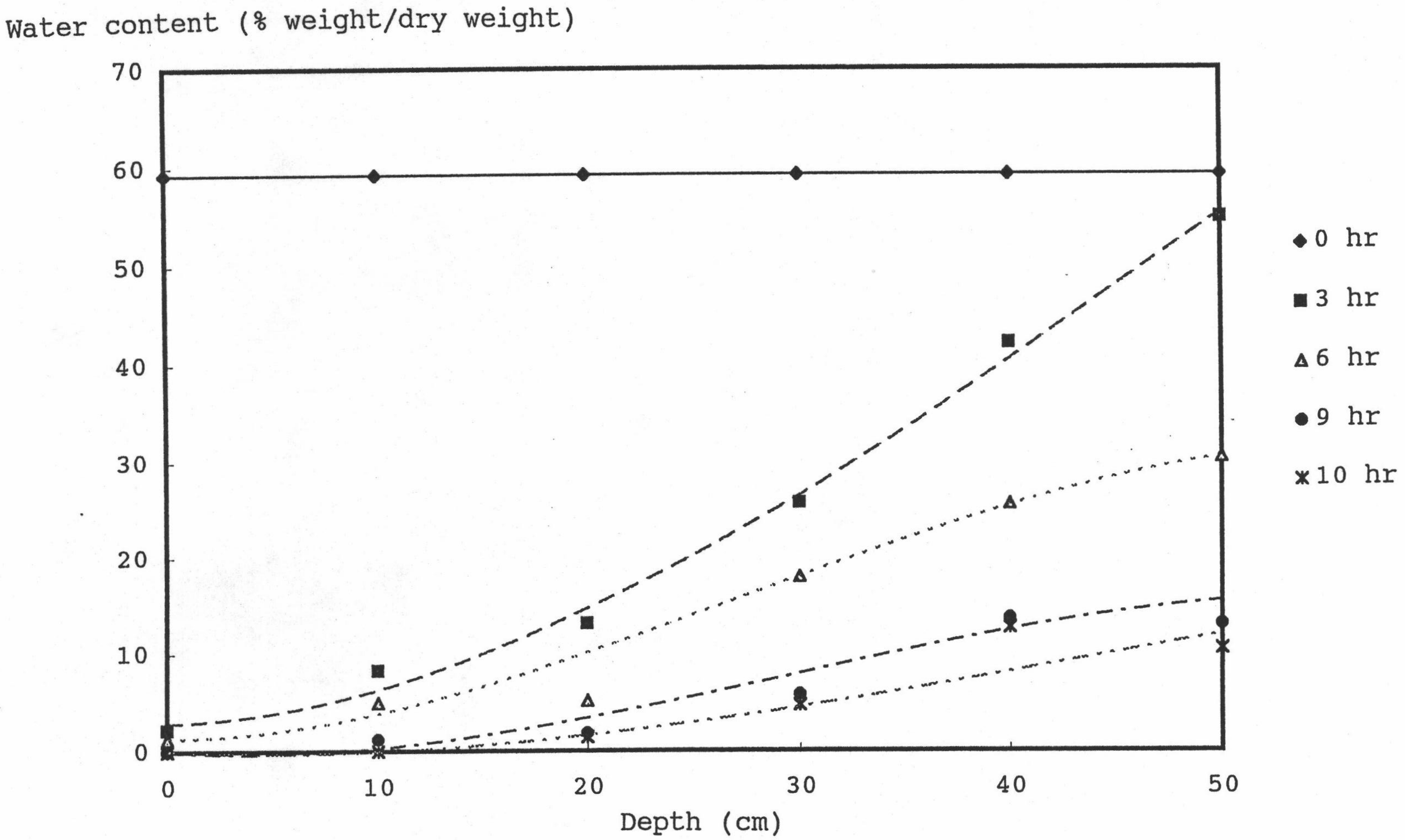

Fig. 4.2 (f) Water content of WAP-free sand column using ambient air conditions : 30 degree Celcius, 40% RH

2 Experimental data for 0.2 % , 0.4 % , 0.5 % WAP

Six sets of experiments which conditions were shown in Table 4.1 were made for each WAP concentration namely 0.2 % WAP ,0.4 % WAP , 0.5 % WAP for a total of 18 sets of experiments shown in Figures 4.3 (a) - (f) , 4.4 (a) - (f) , 4.5 (a) - (f). All the figures shown in the same way that the initial water contents of sand column containing WAP were higher than those of WAP-free sand columns except 0.2 % WAP containing sand columns which initial water contents were nearly equal to those of WAP-free sand columns. After 3 hours of experiments, water contents at the surface of the sand columns were about 20% less than initial water contents and still equaled to the initial water contents at the bottom. On the last period of experiments water contents at the bottom of the column decreased no more than 20% comparing with the initial water contents and at the surface those still retained about half of them when the experiments started. The corresponding data is presented in appendix A-11 to A-16, appendix A-17 to A-22, and apendix A-23 to A-28.

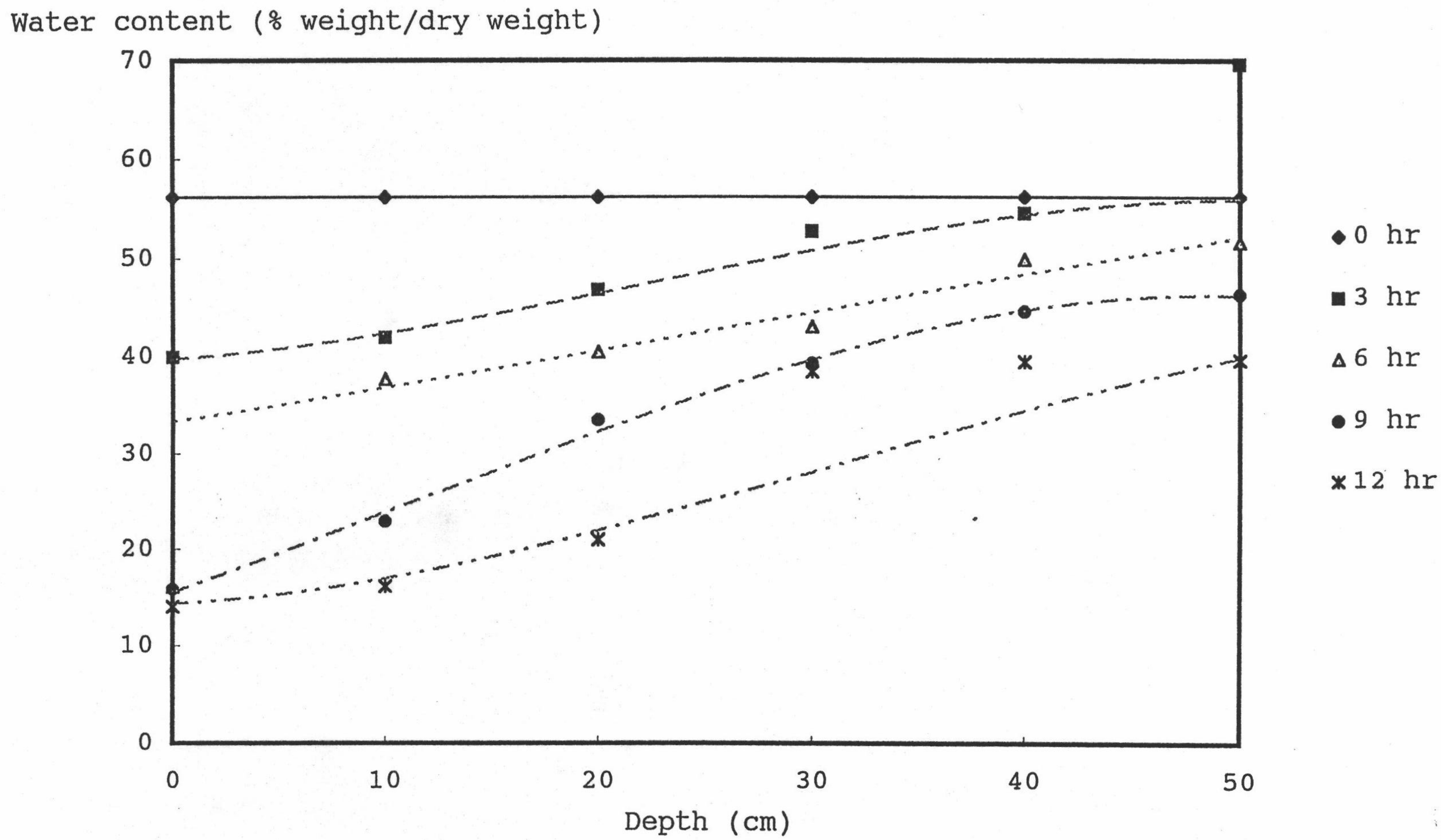

Fig. 4.3(a) Water content of sand column containing 0.2%WAP by weight using ambient air conditions : 50 degree Celcius, 25% RH

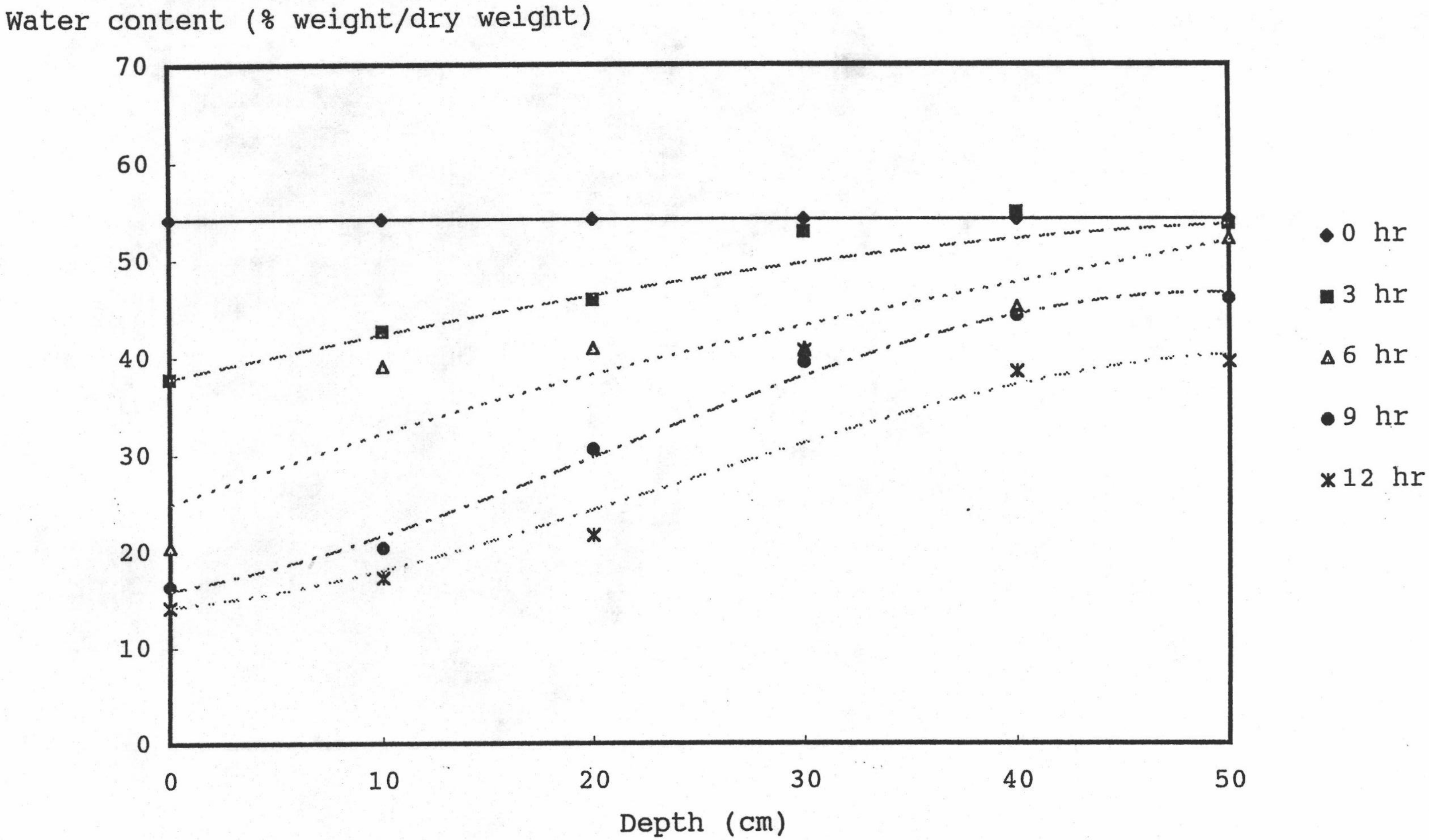

Fig. 4.3(b) Water content of sand column containing 0.2%WAP by weight using ambient air conditions : 50 degree Celcius, 40% RH

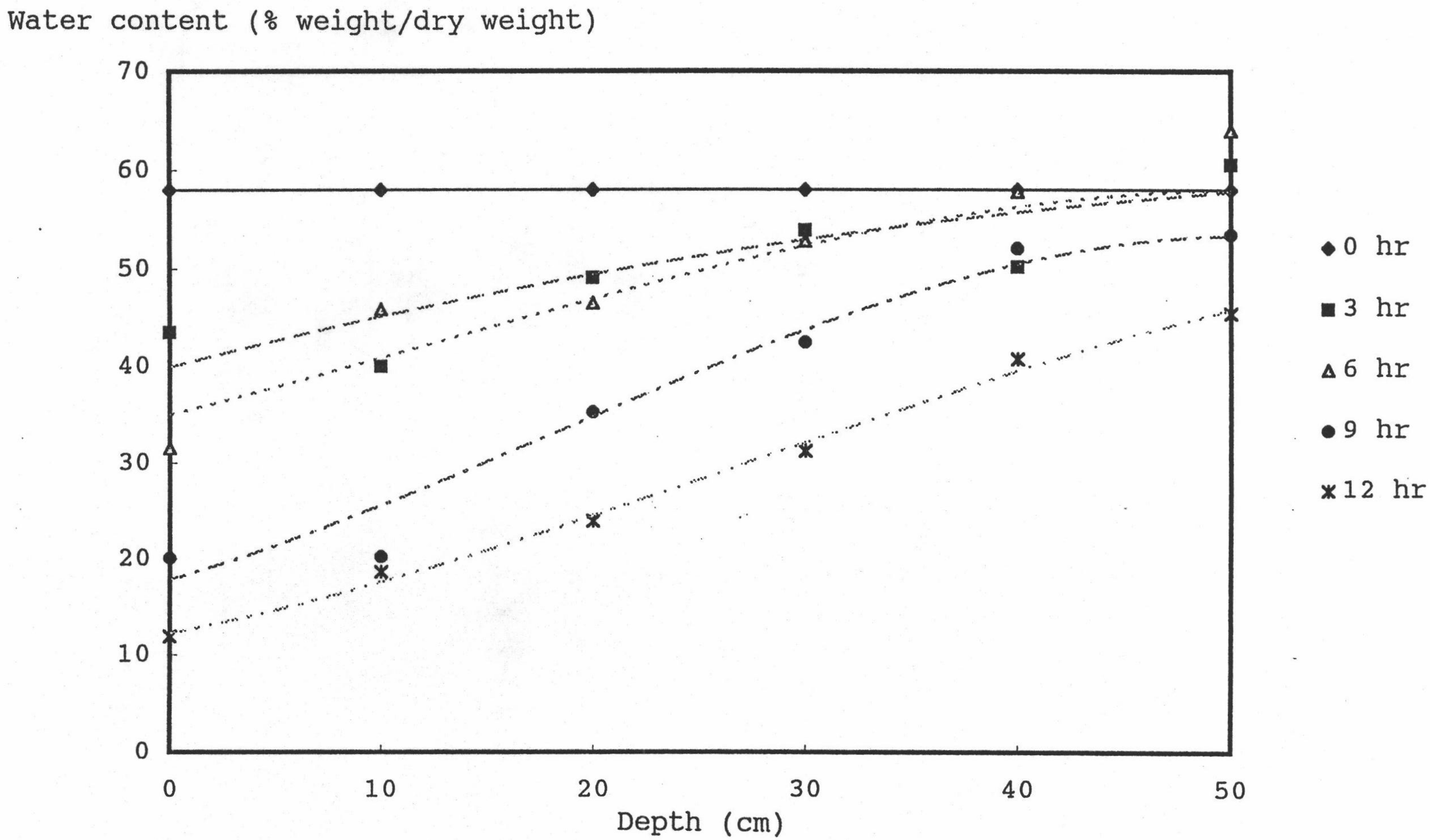

Fig. 4.3(c) Water content of sand column containing 0.2%WAP by weight using ambient air conditions : 40 degree Celcius, 25% RH

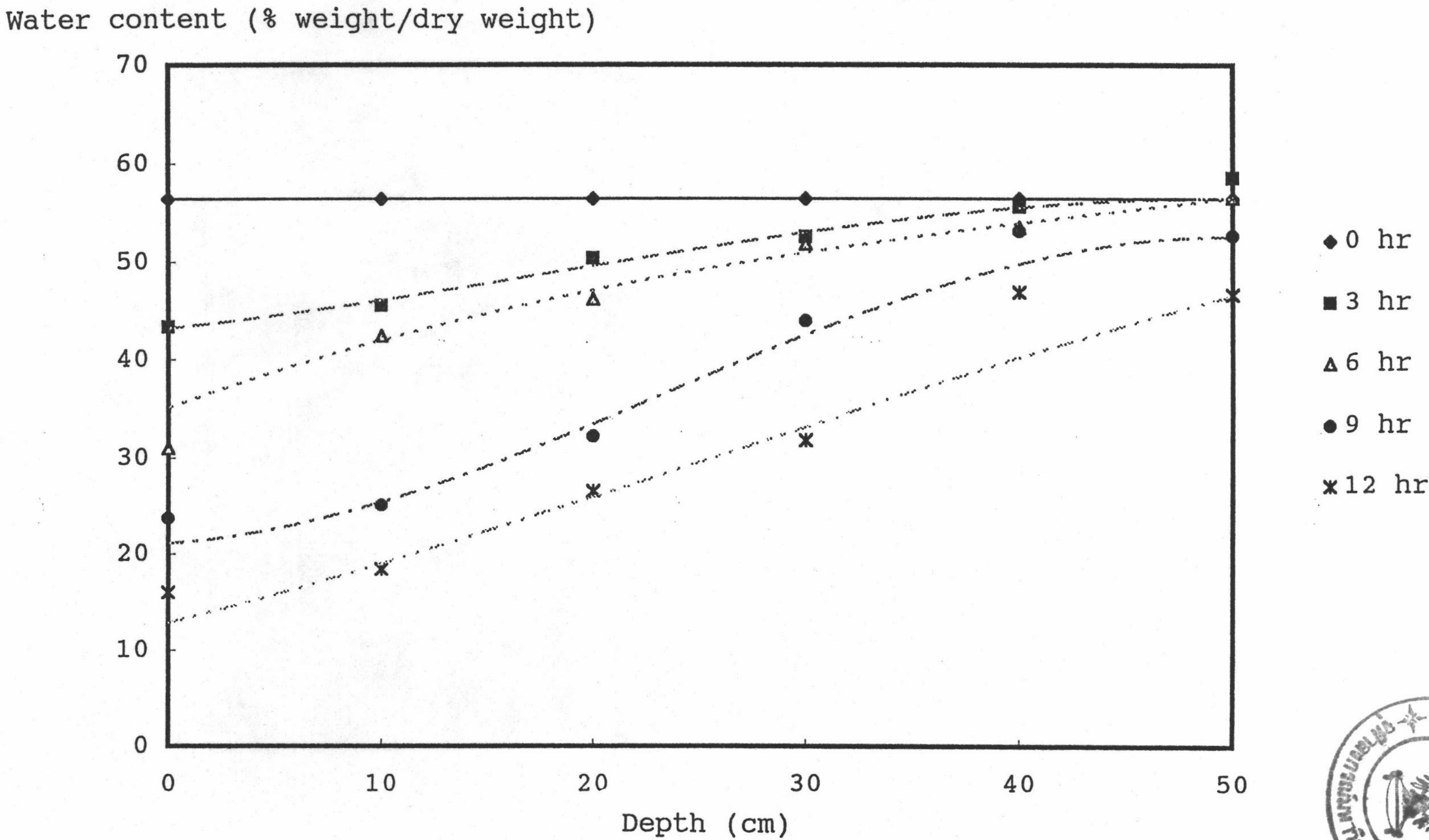

Fig. 4.3(d) Water content of sand column containing 0.2%WAP by weight using ambient air conditions : 40 degree Celcius, 40% RH

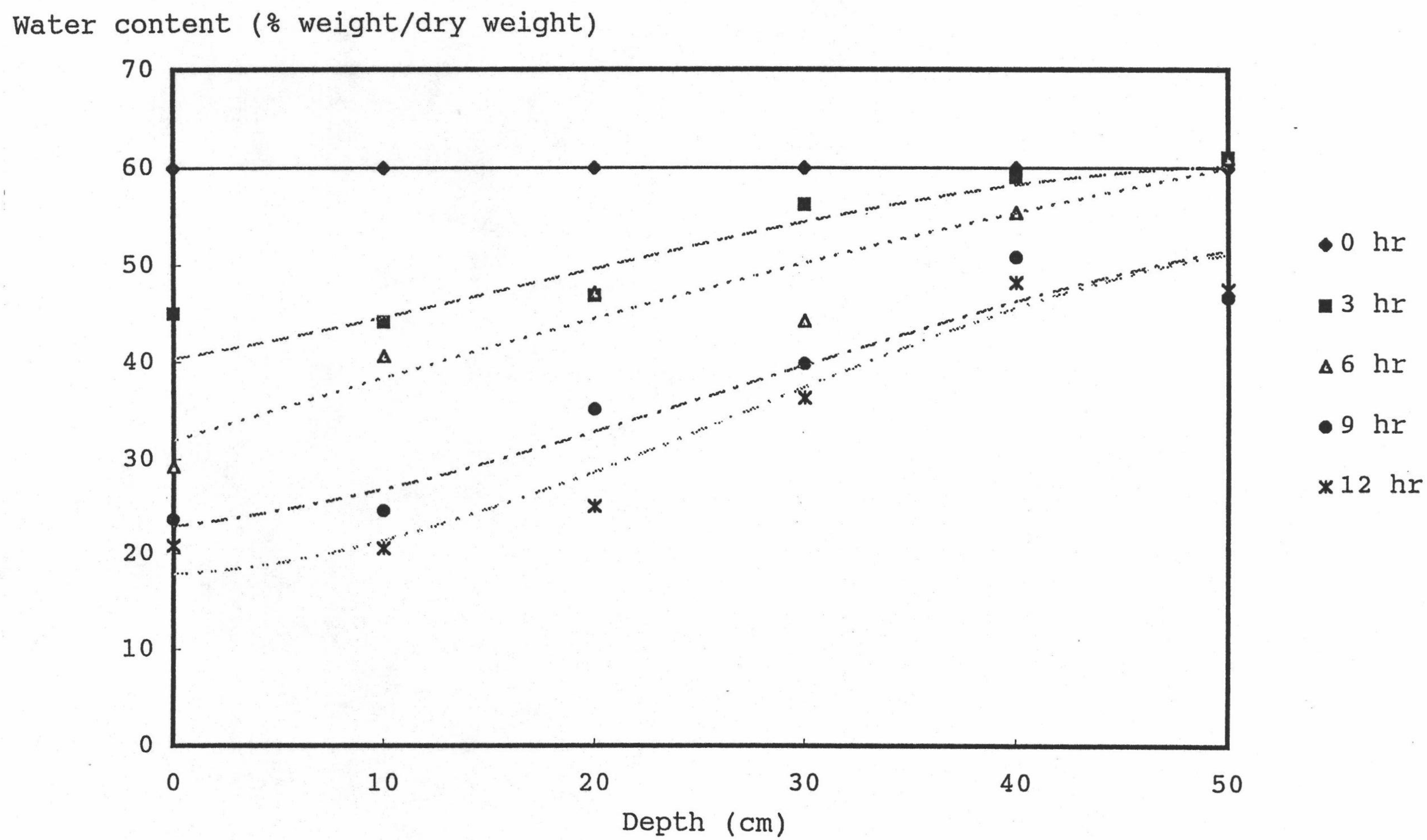

Fig. 4.3(e) Water content of sand column containing 0.2%WAP by weight using ambient air conditions : 30 degree Celcius, 25% RH

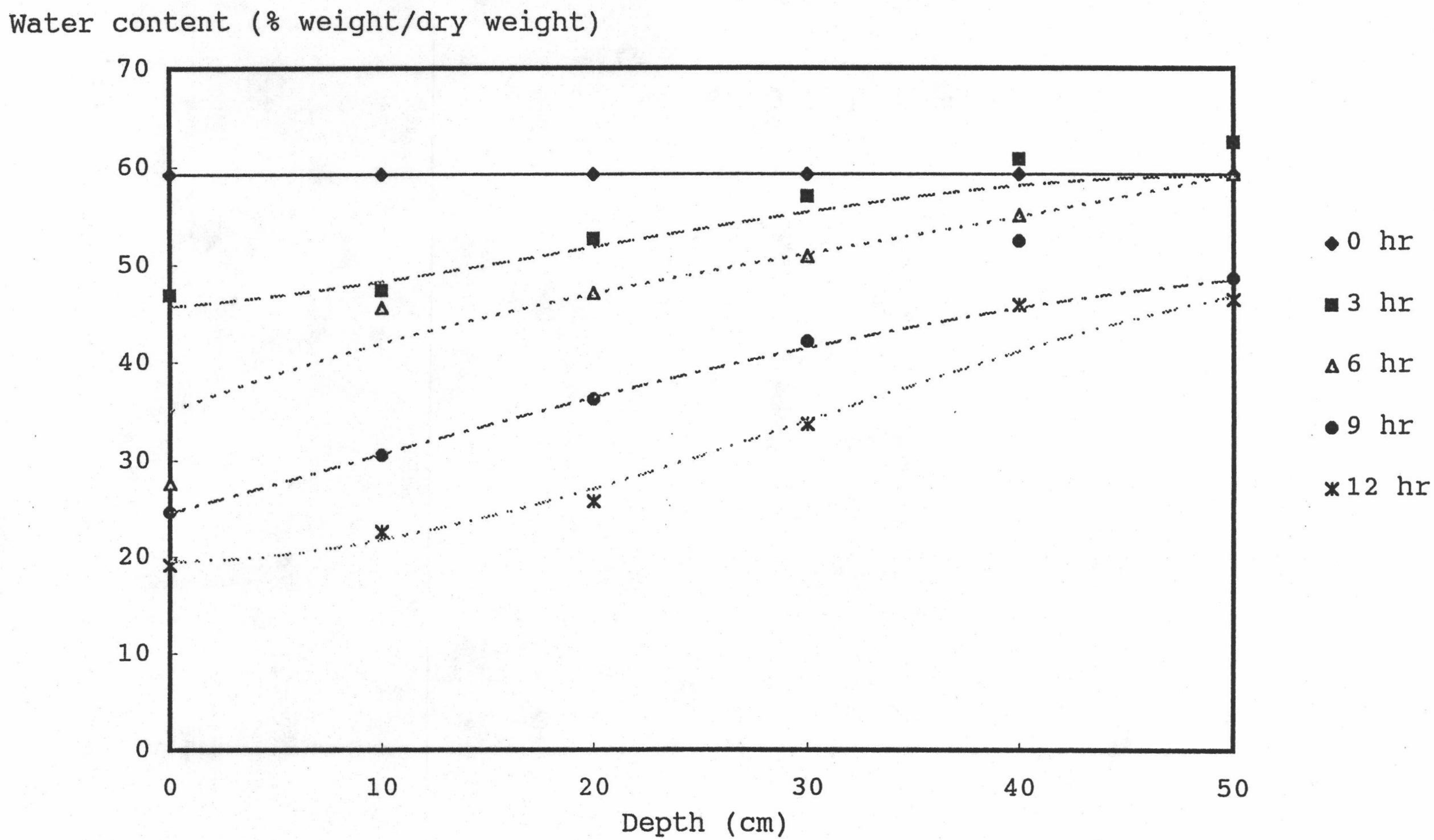

Fig. 4.3(f) Water content of sand column containing 0.2%WAP by weight using ambient air conditions : 30 degree Celcius, 40% RH

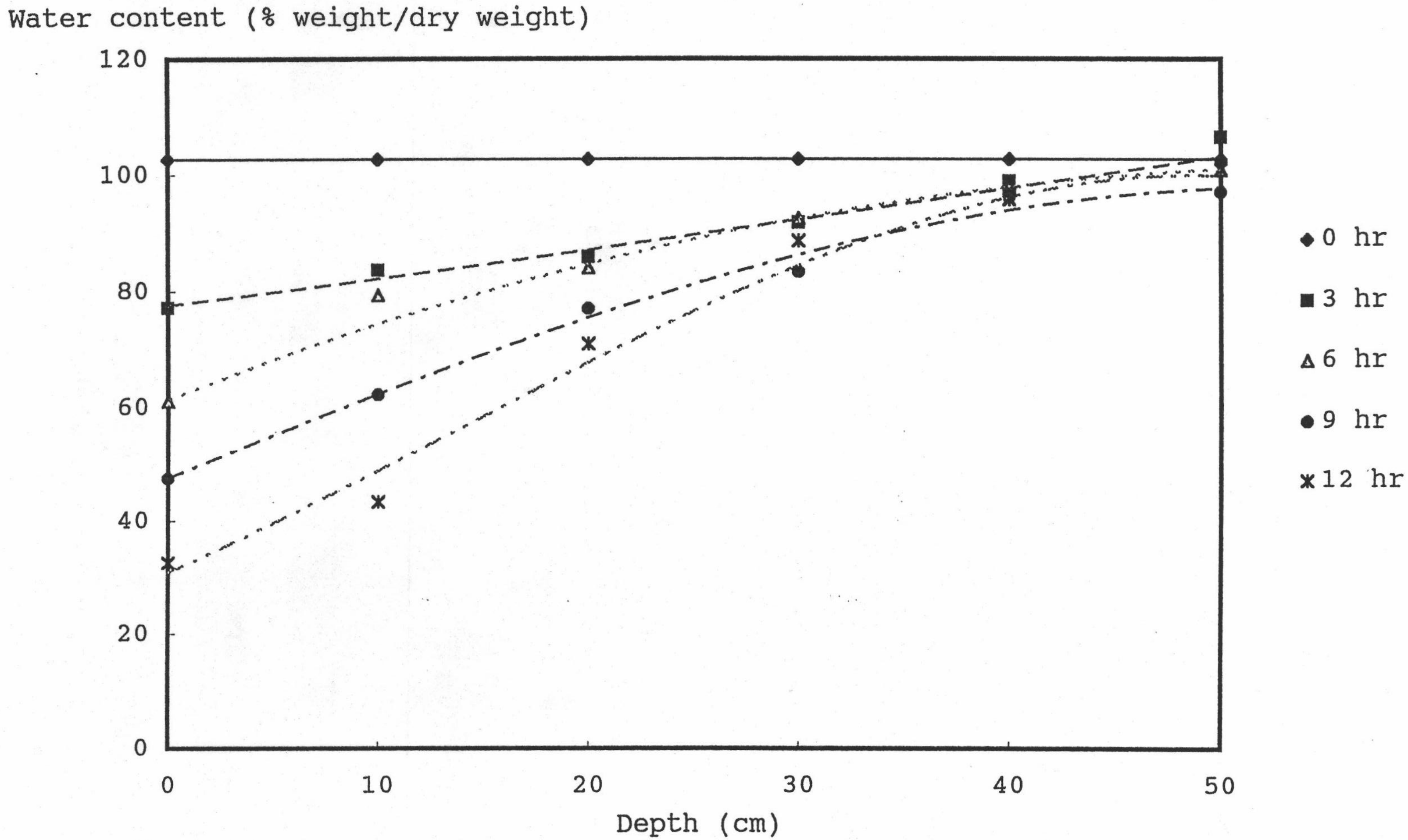

Fig. 4.4(a) Water content of sand column containing 0.4%WAP by weight using ambient air conditions : 50 degree Celcius, 25% RH

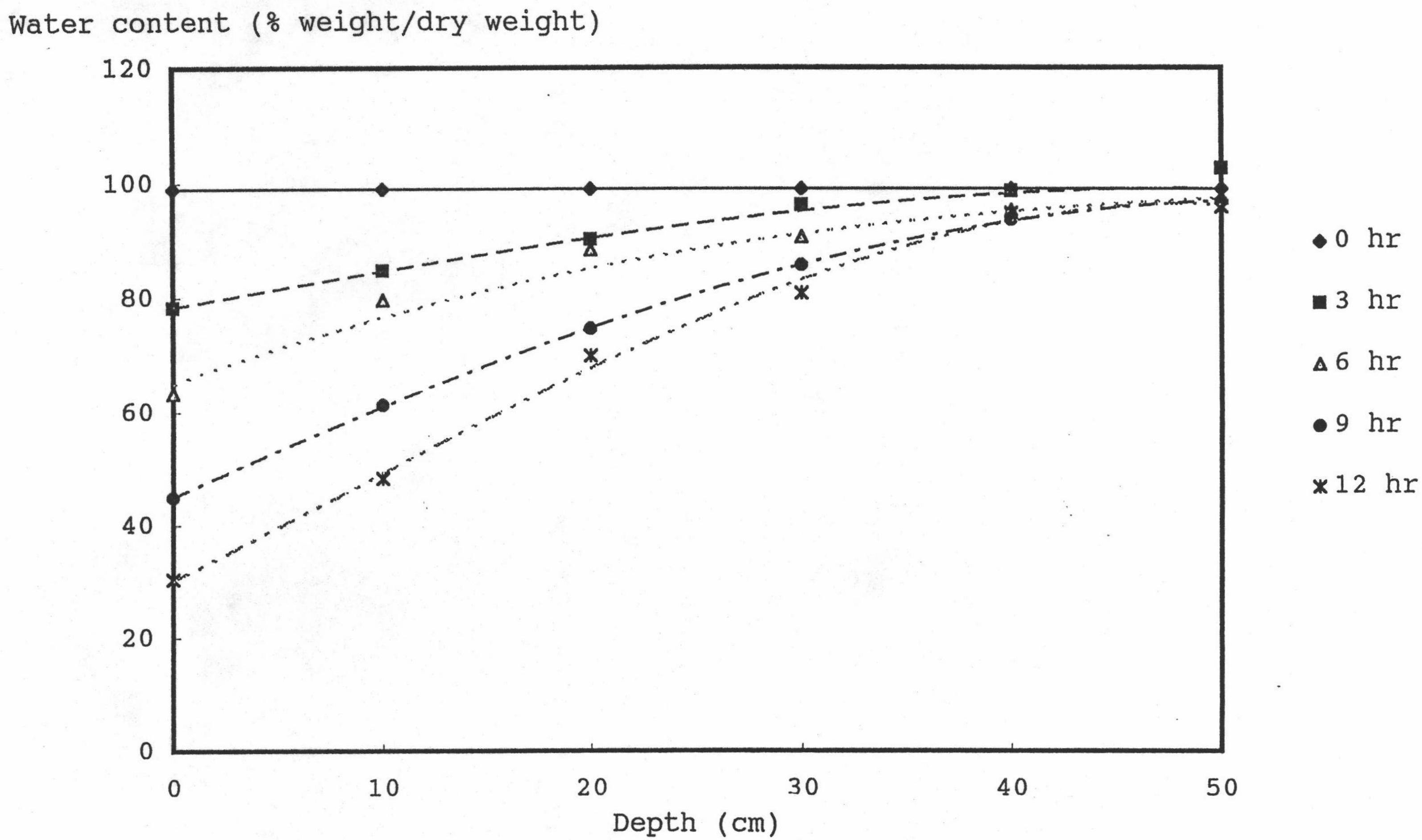

Fig. 4.4(b) Water content of sand column containing 0.4%WAP by weight using ambient air conditions : 50 degree Celcius, 40% RH

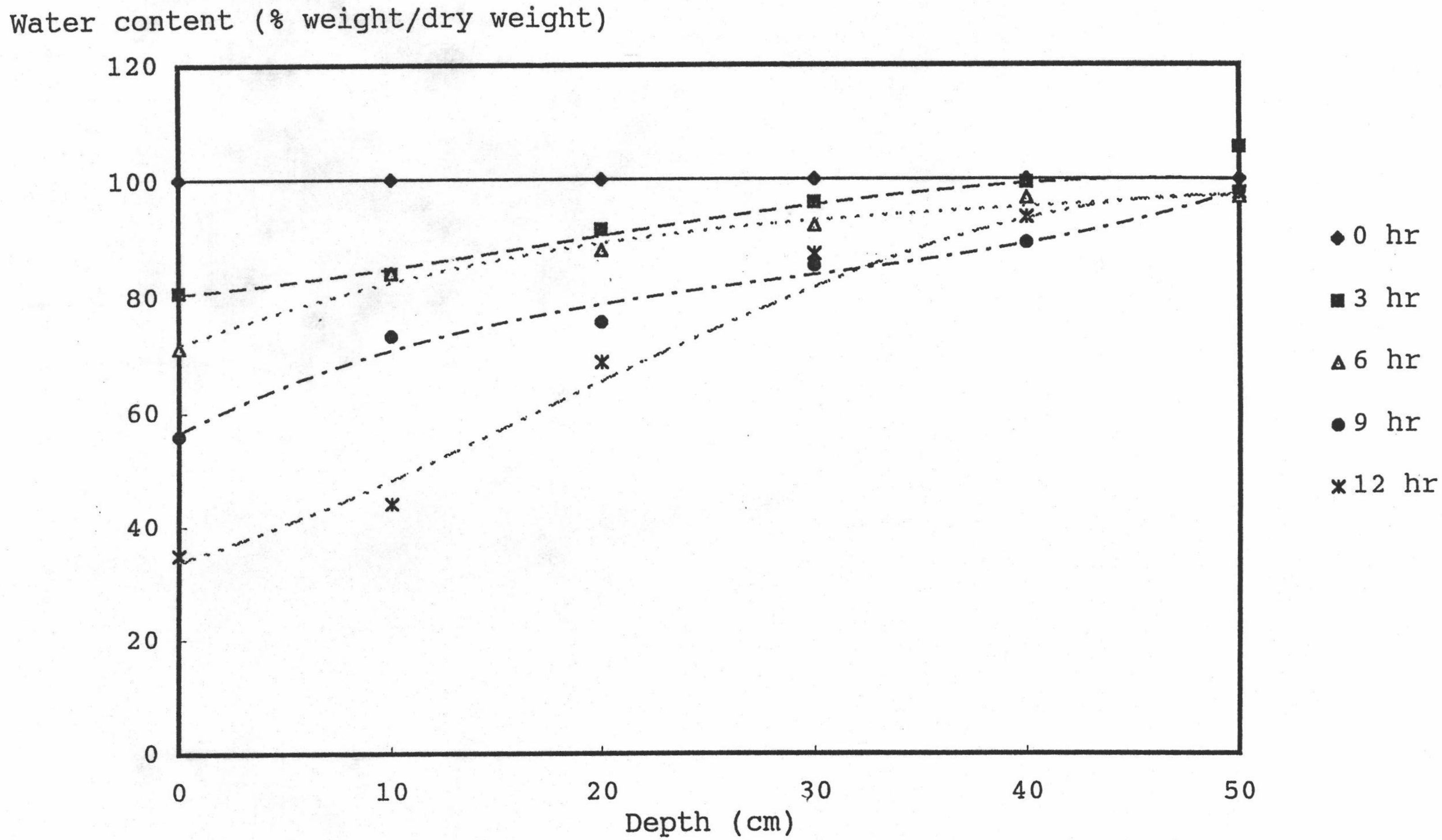

Fig. 4.4(c) Water content of sand column containing 0.4%WAP by weight using ambient air conditions : 40 degree Celcius, 25% RH

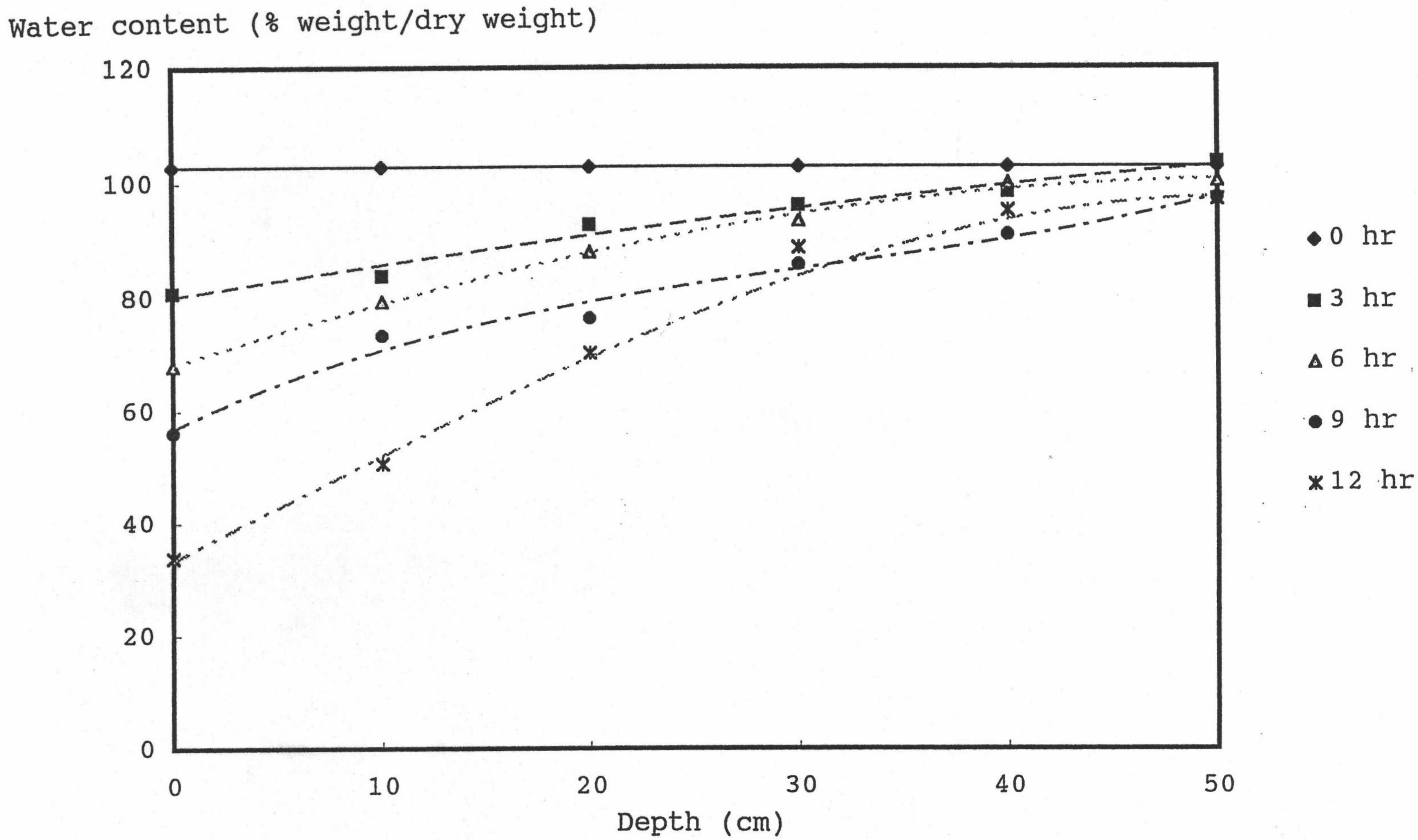

Fig. 4.4(d) Water content of sand column containing 0.4%WAP by weight using ambient air conditions : 40 degree Celcius, 40% RH

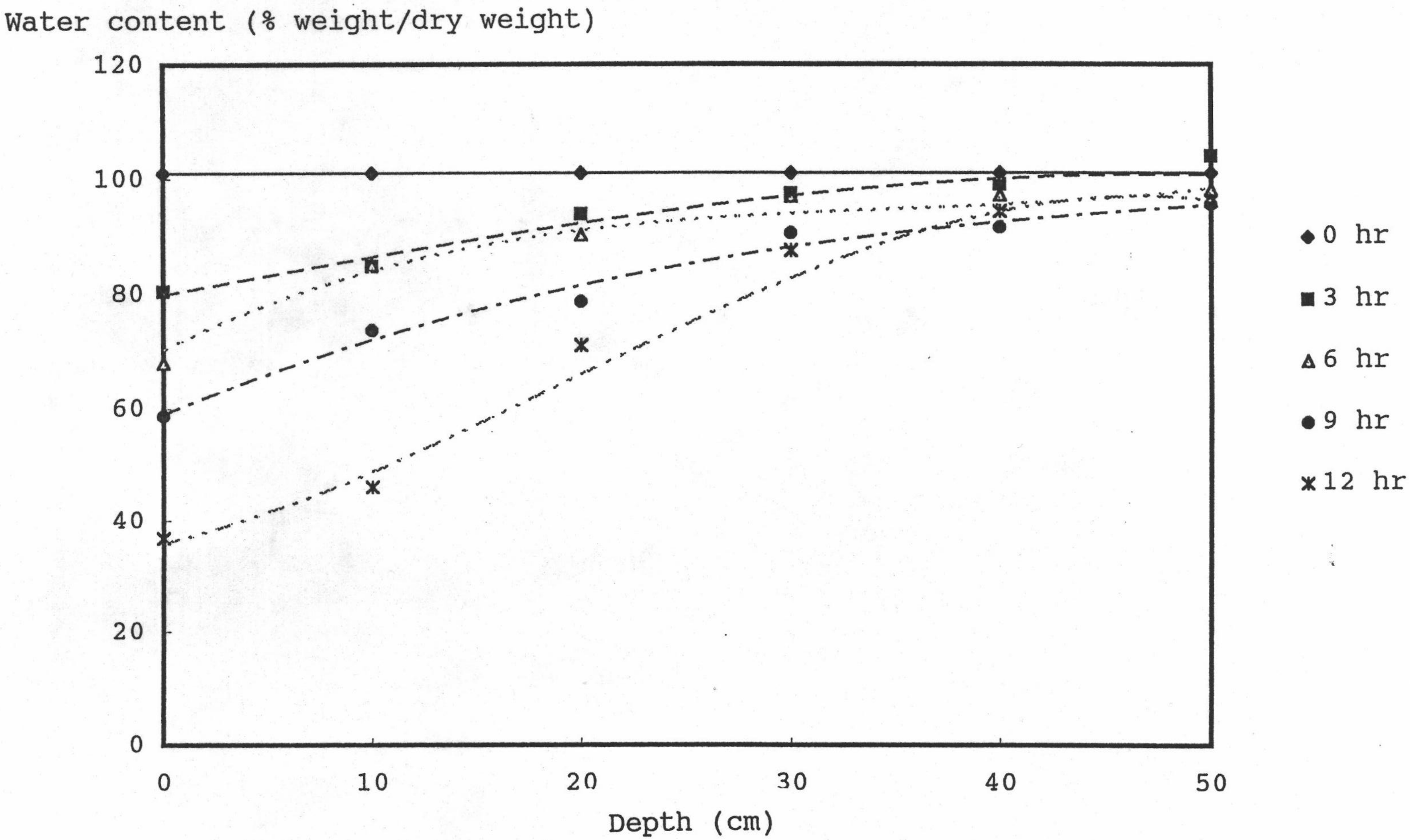

Fig. 4.4(e) Water content of sand column containing 0.4%WAP by weight using ambient air conditions : 30 degree Celcius, 25% RH

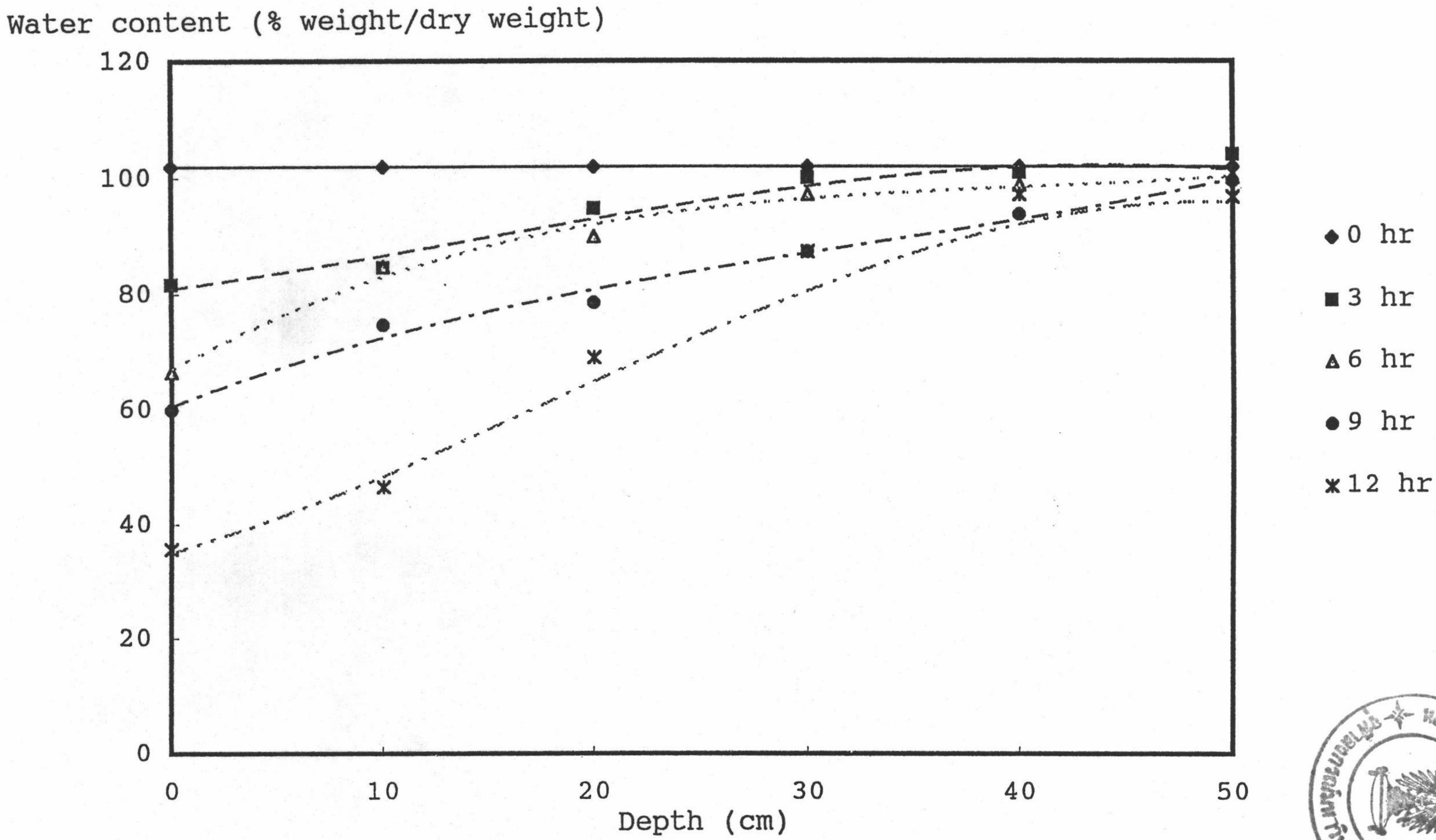

Fig. 4.4(f) Water content of sand column containing 0.4%WAP by weight using ambient air conditions : 30 degree Celcius, 40% RH

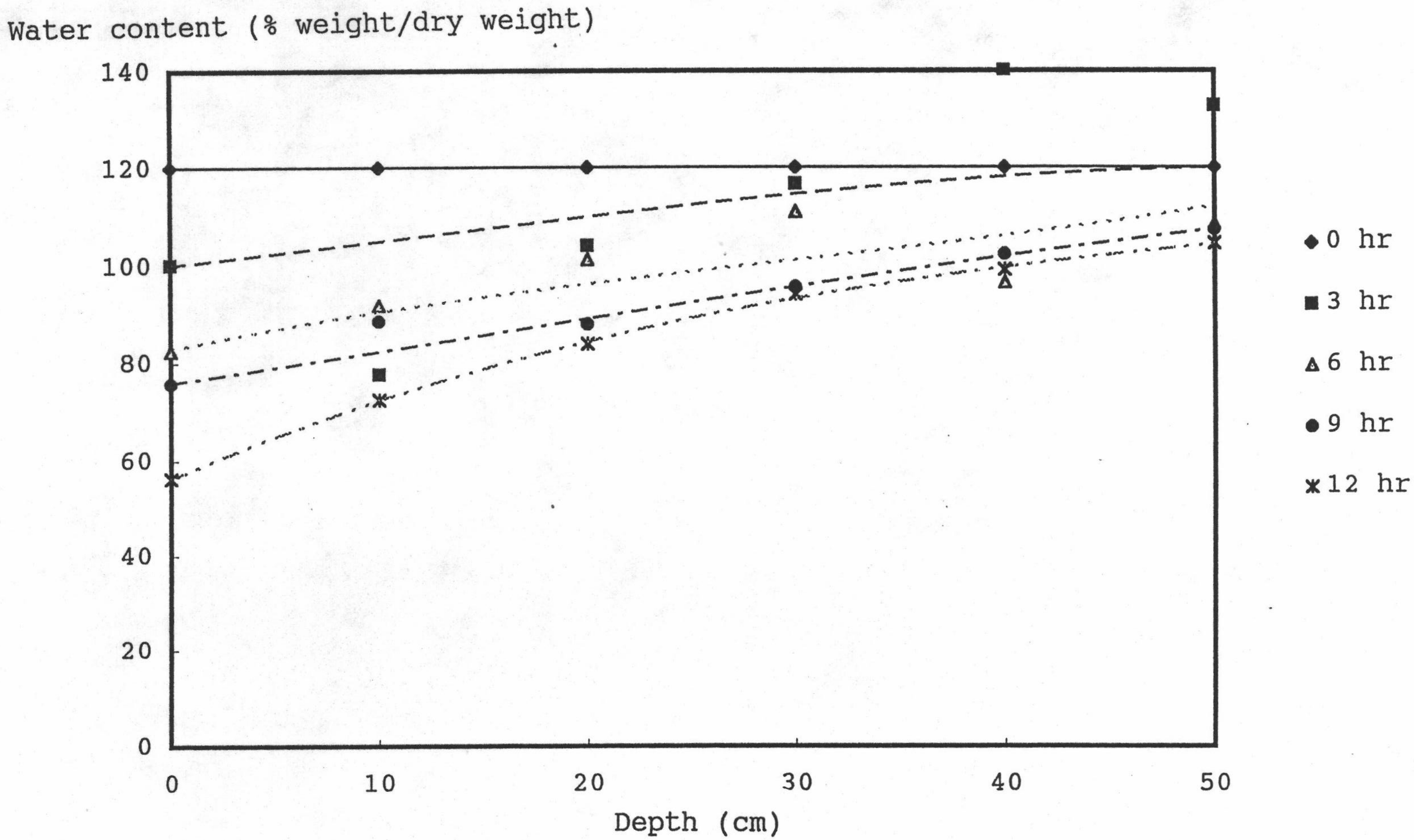

Fig. 4.5(a) Water content of sand column containing 0.5%WAP by weight using ambient air conditions : 50 degree Celcius, 25% RH

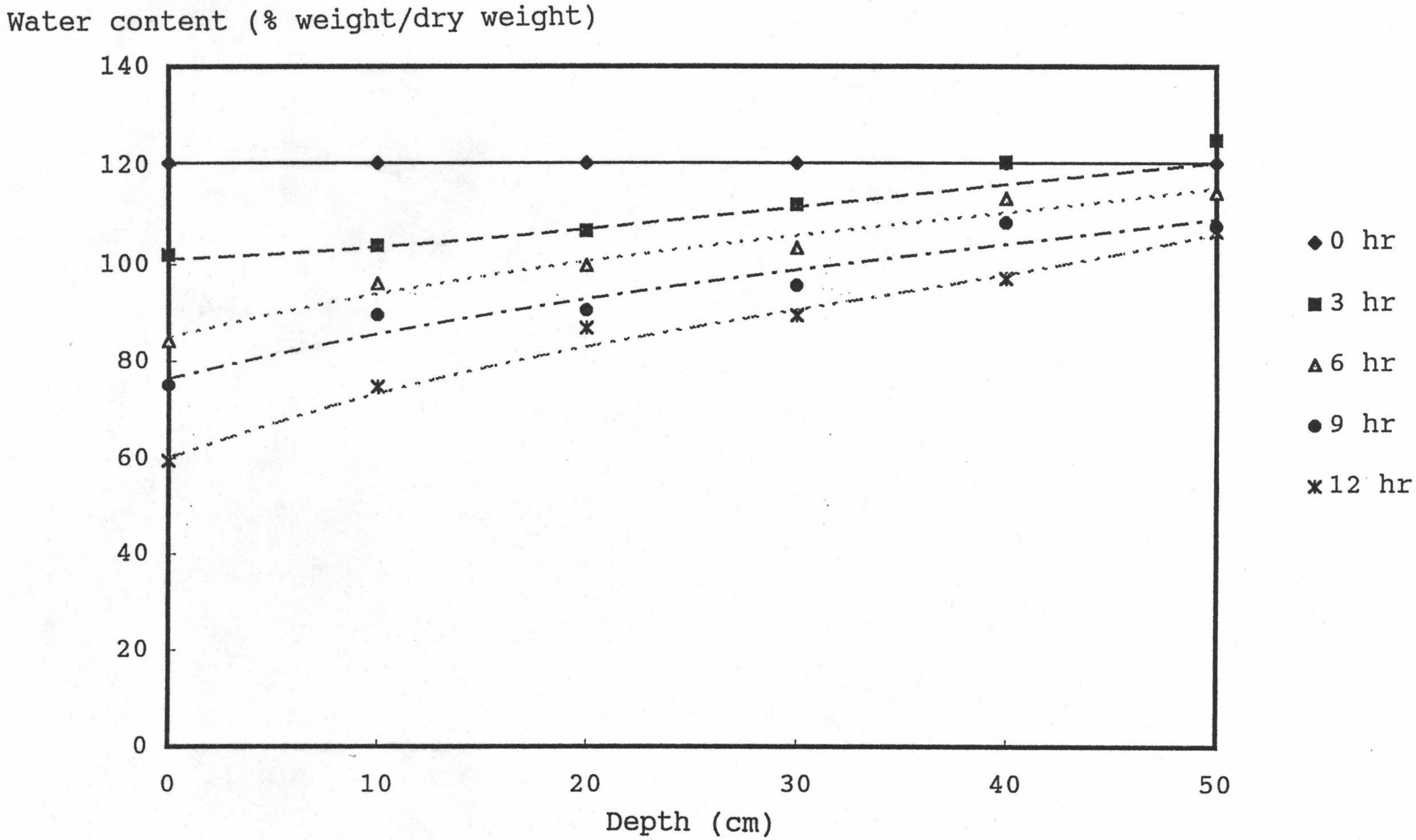

Fig. 4.5(b) Water content of sand column containing 0.5%WAP by weight using ambient air conditions : 50 degree Celcius, 40% RH

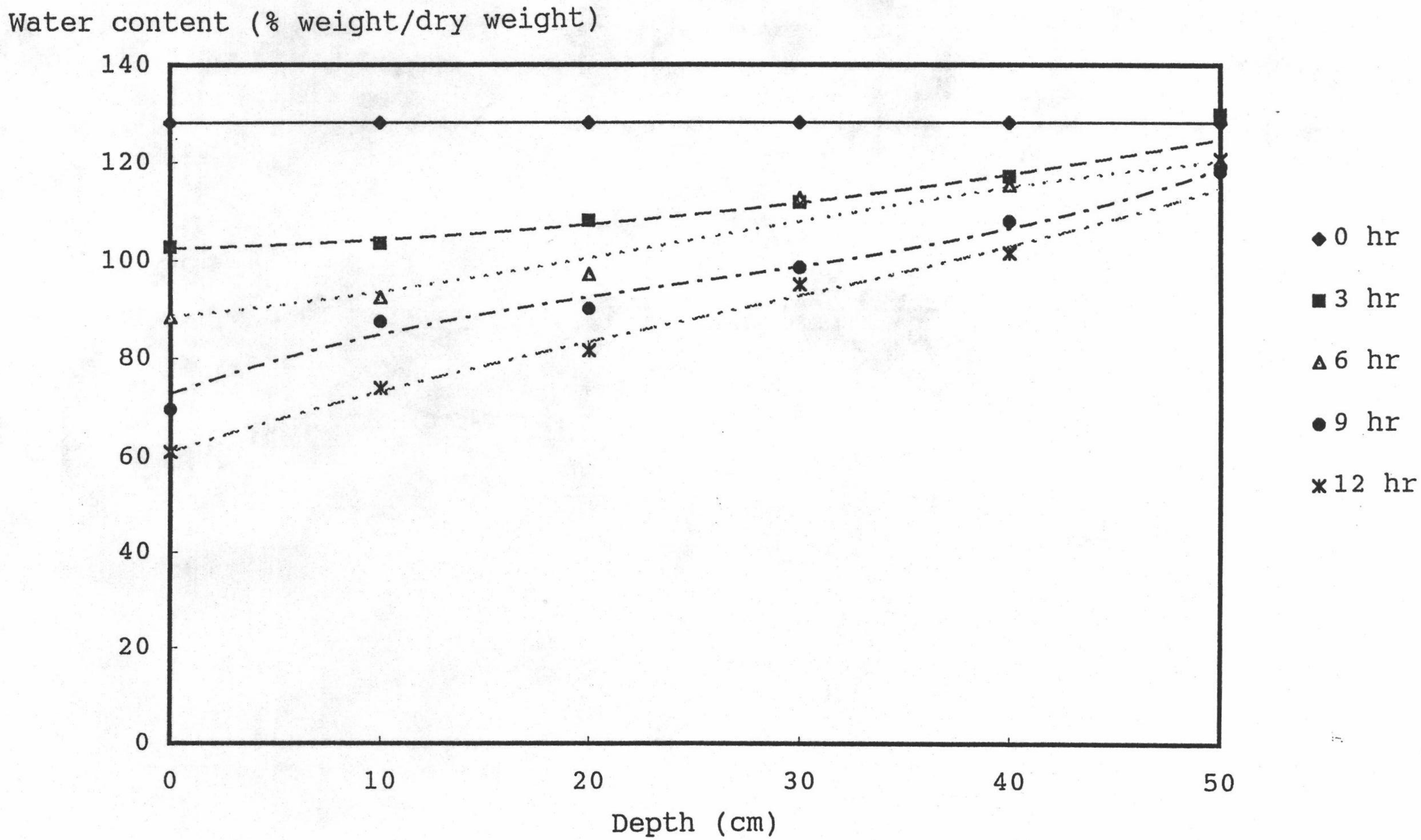

Fig. 4.5(c) Water content of sand column containing 0.5%WAP by weight using ambient air conditions : 40 degree Celcius, 25% RH

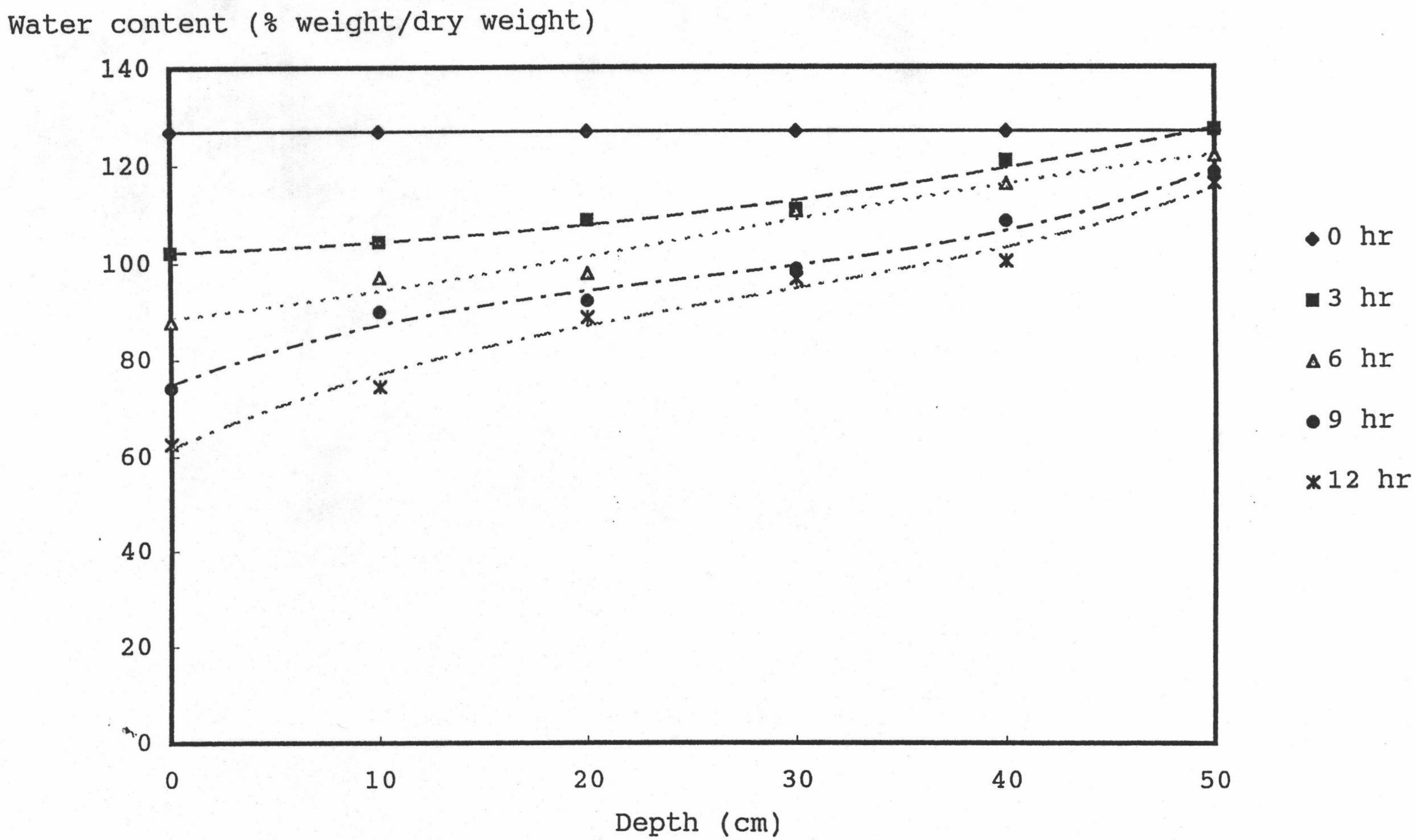

Fig. 4.5(d) Water content of sand column containing 0.5%WAP by weight using ambient air conditions : 40 degree Celcius, 40% RH

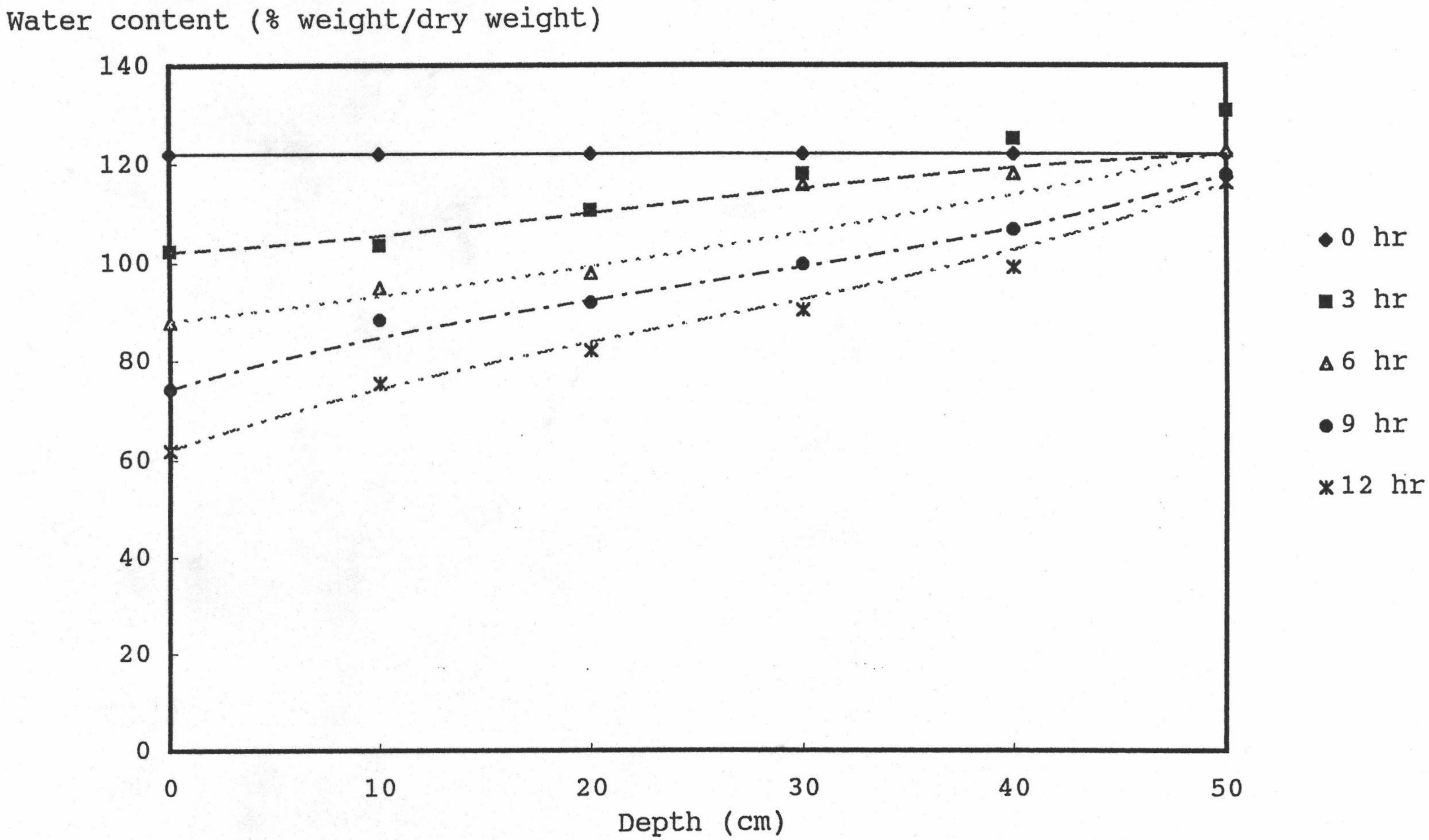

Fig. 4.5(e) Water content of sand column containing 0.5%WAP by weight using ambient air conditions : 30 degree Celcius, 25% RH

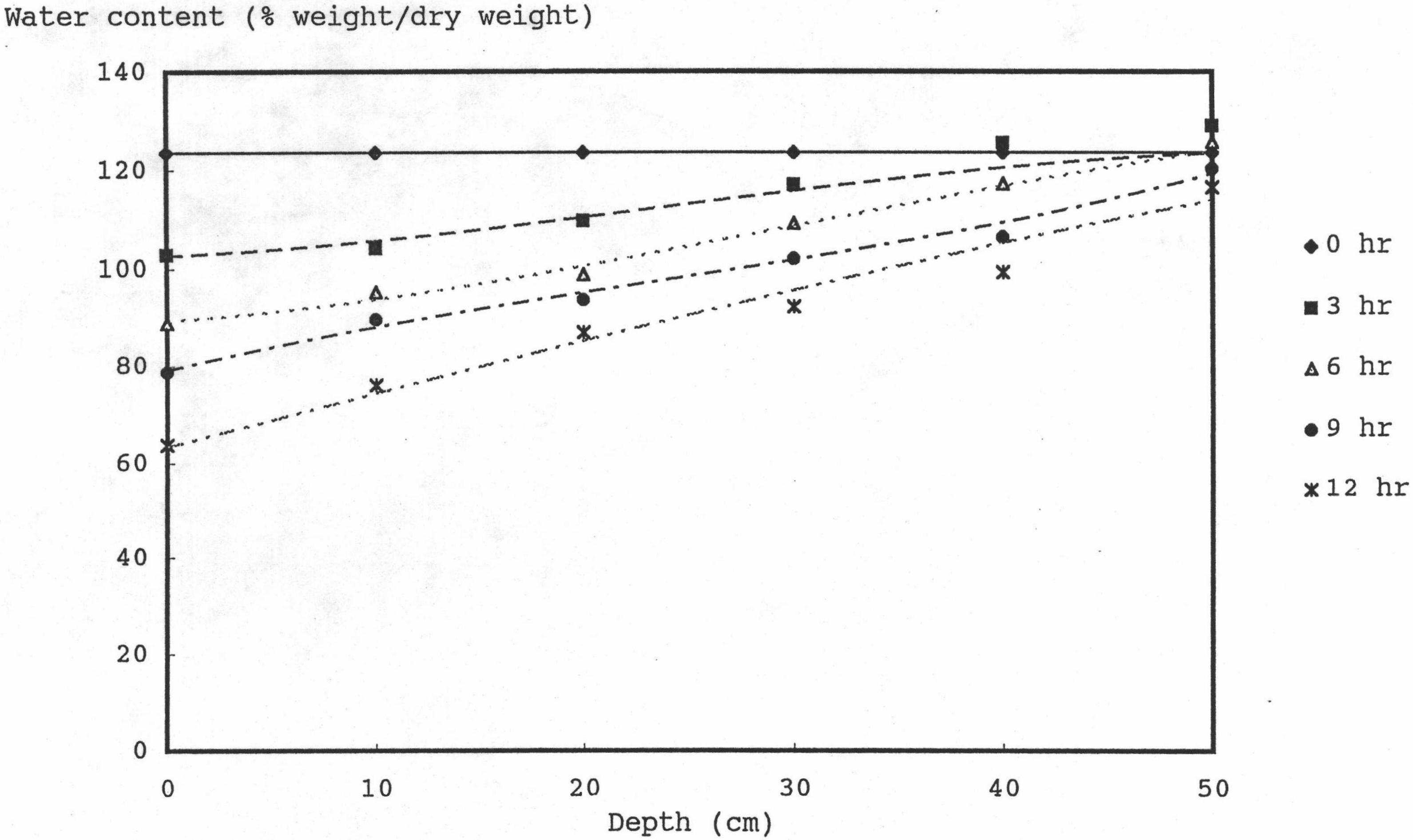

Fig. 4.5(f) Water content of sand column containing 0.5%WAP by weight using ambient air conditions : 30 degree Celcius, 40% RH

Influence on WAP on relative evaporation

In order to compare the influence of WAP on water retention, data was compared for four concentrations of WAP as a function of time with each set of data based on initial water concentration. The data shown in Figures 4.6 (a) - (d) are thus ratios, meaning water contents devided by initial water contents. The data indicates that WAP containing sands are vastly superior at retaining water over the twelve hours these experiments lasted. In particular after 12 hours the ratio of water contained in the sand column based on initial water content was 5.1% whereas the ratio of water contained in the sand column plus 0.2% WAP was 47.8% ; for the sand column plus 0.4% WAP this ratio was 71.3% ; for the sand column plus 0.5% WAP this ratio was 71.0%.

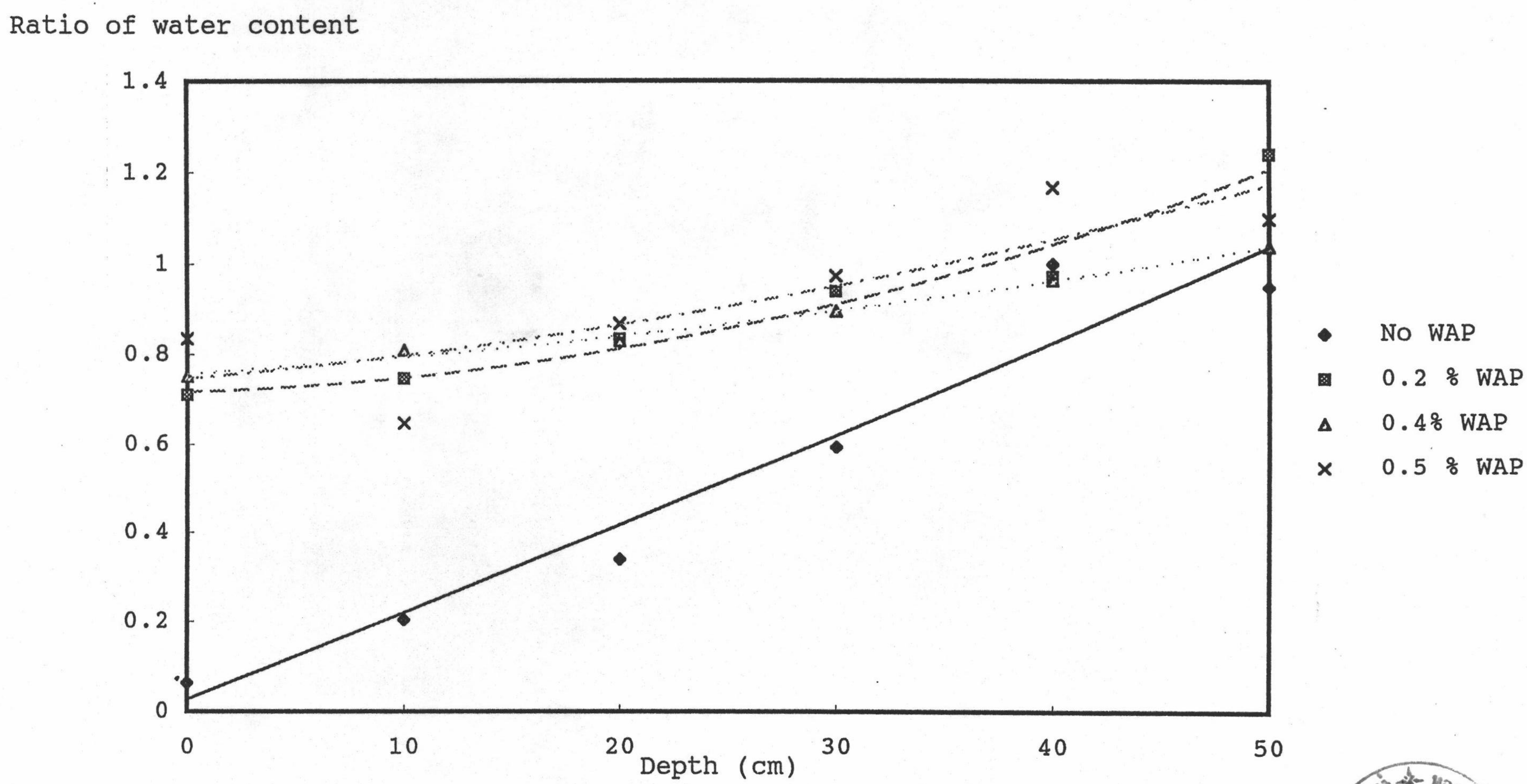

Fig. 4.6(a) Ratio of the average water content at different depth interval after 3 hours of experiment pass, using ambient air conditions : 50 degree Celcius, 25% RH

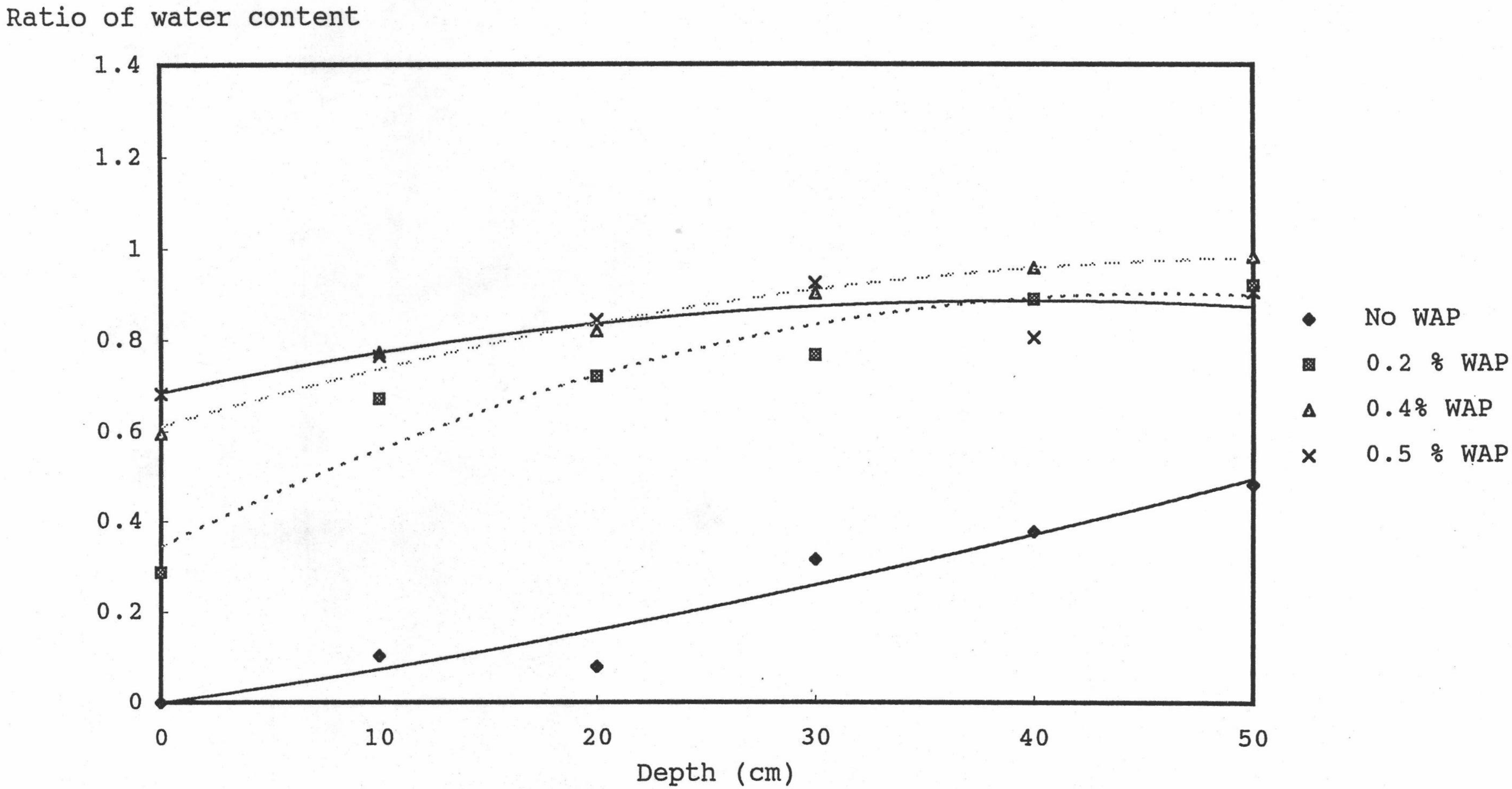

Fig. 4.6(b) Ratio of the average water content at different depth interval after 6 hours of experiment pass, using ambient air conditions : 50 degree Celcius, 25% RH

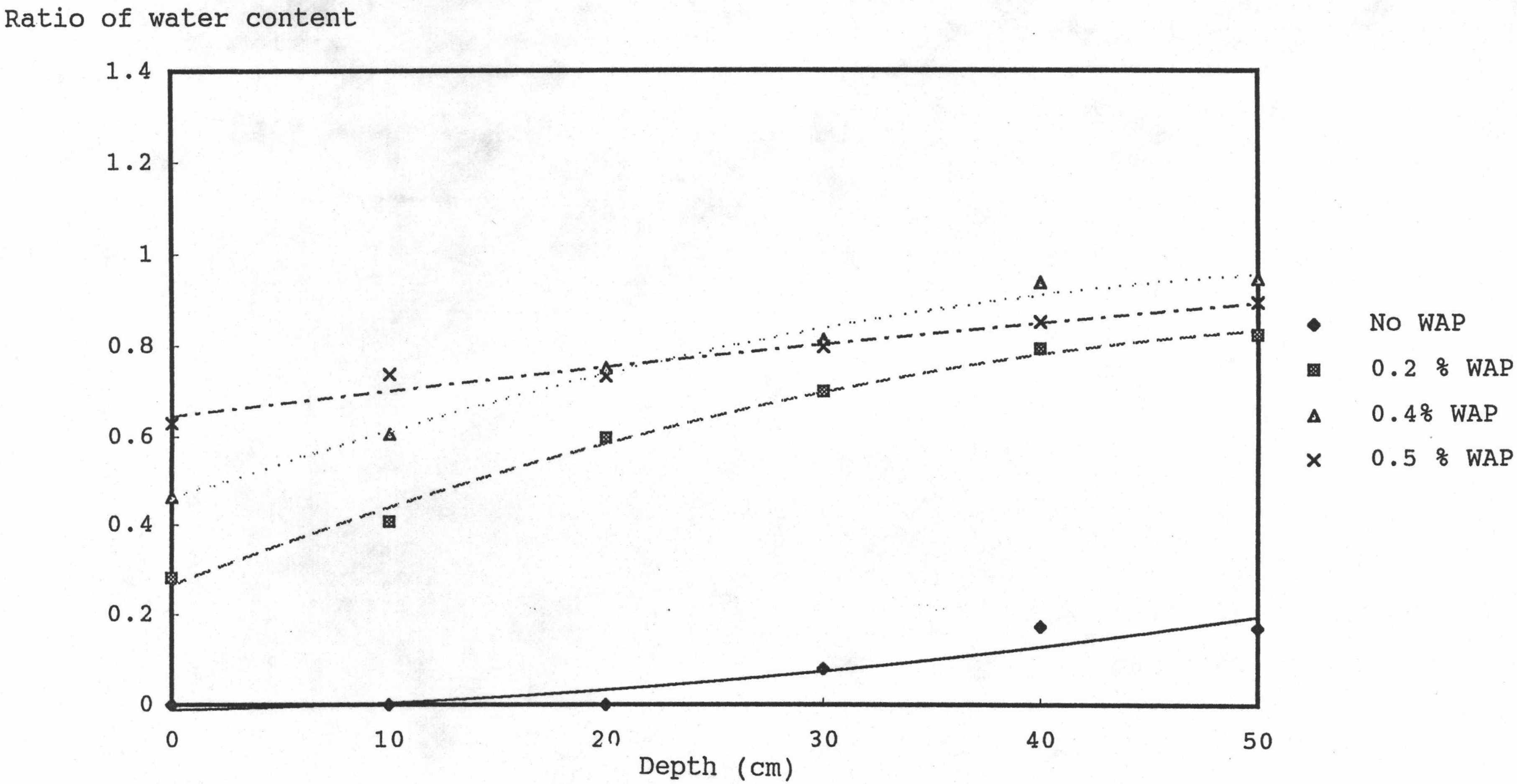

Fig. 4.6(c) Ratio of the average water content at different depth interval after 9 hours of experiment pass, using ambient air conditions : 50 degree Celcius, 25% RH

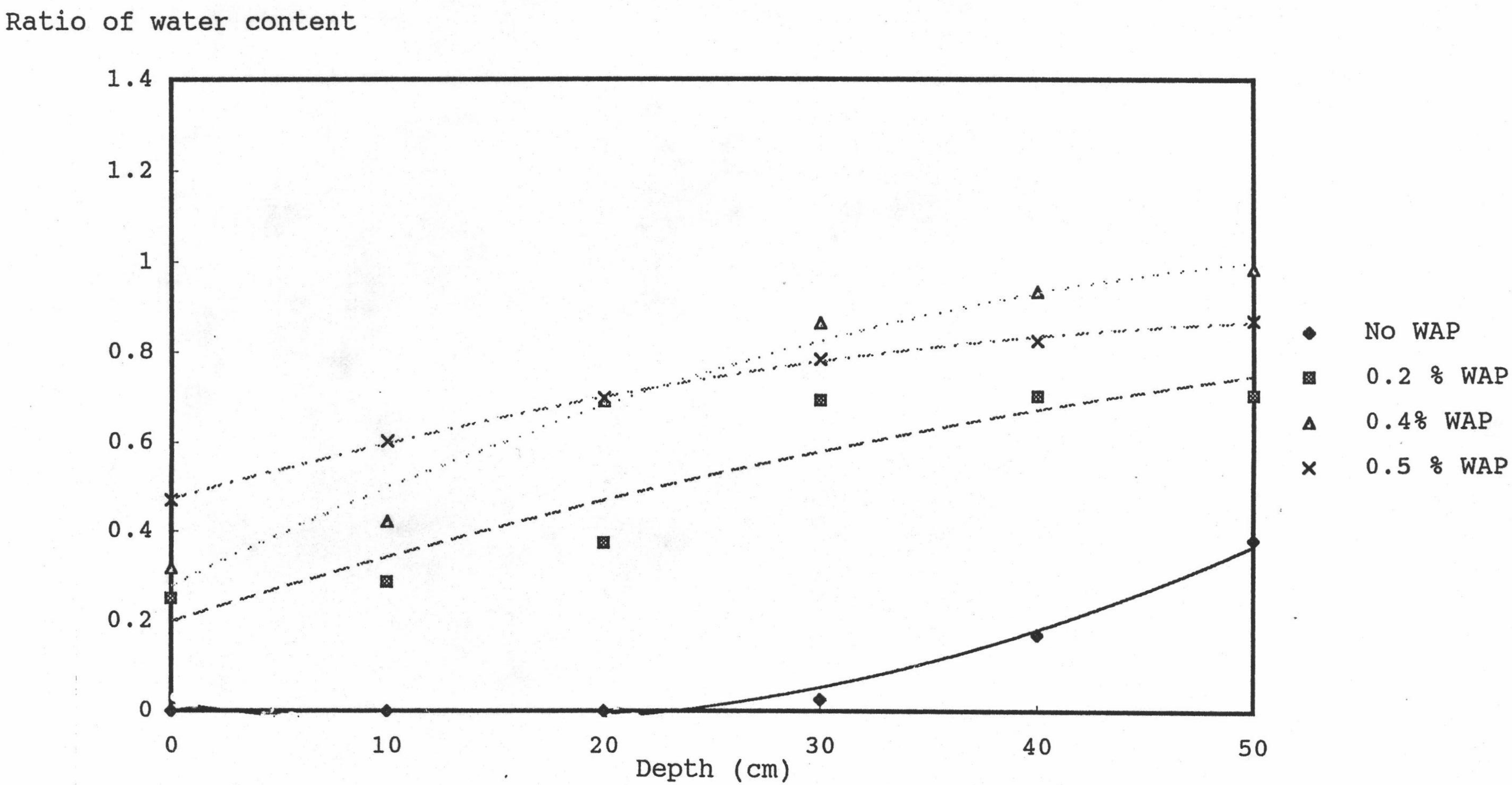

Fig. 4.6(d) Ratio of the average water content at different depth interval after 12 hours of experiment pass, using ambient air conditions : 50 degree Celcius, 25% RH

Measurements of dispersion coefficients for water transport in the sand column .

In order calculate dispersion coefficients for water transport in the sand volumn that would allow an empirical understanding of the phenomena it was assumed as mentioned earlier that the dispersion coefficients could be simulated by Dr = am + (1-a) or by Dr = m^a or by Dr = exp (a(m-1)) to be called Type 1 , Type 2 , Type 3 coefficient equations .

Figure 4.7 shows one attempt at measuring the error in the numerical optimization in the search for the best equation type. From the data obtained it would seem that the linear form of the diffusion equation and the power form of the diffusion equation yield a better fit to the experiment data than the exponential form of the diffusion equation.

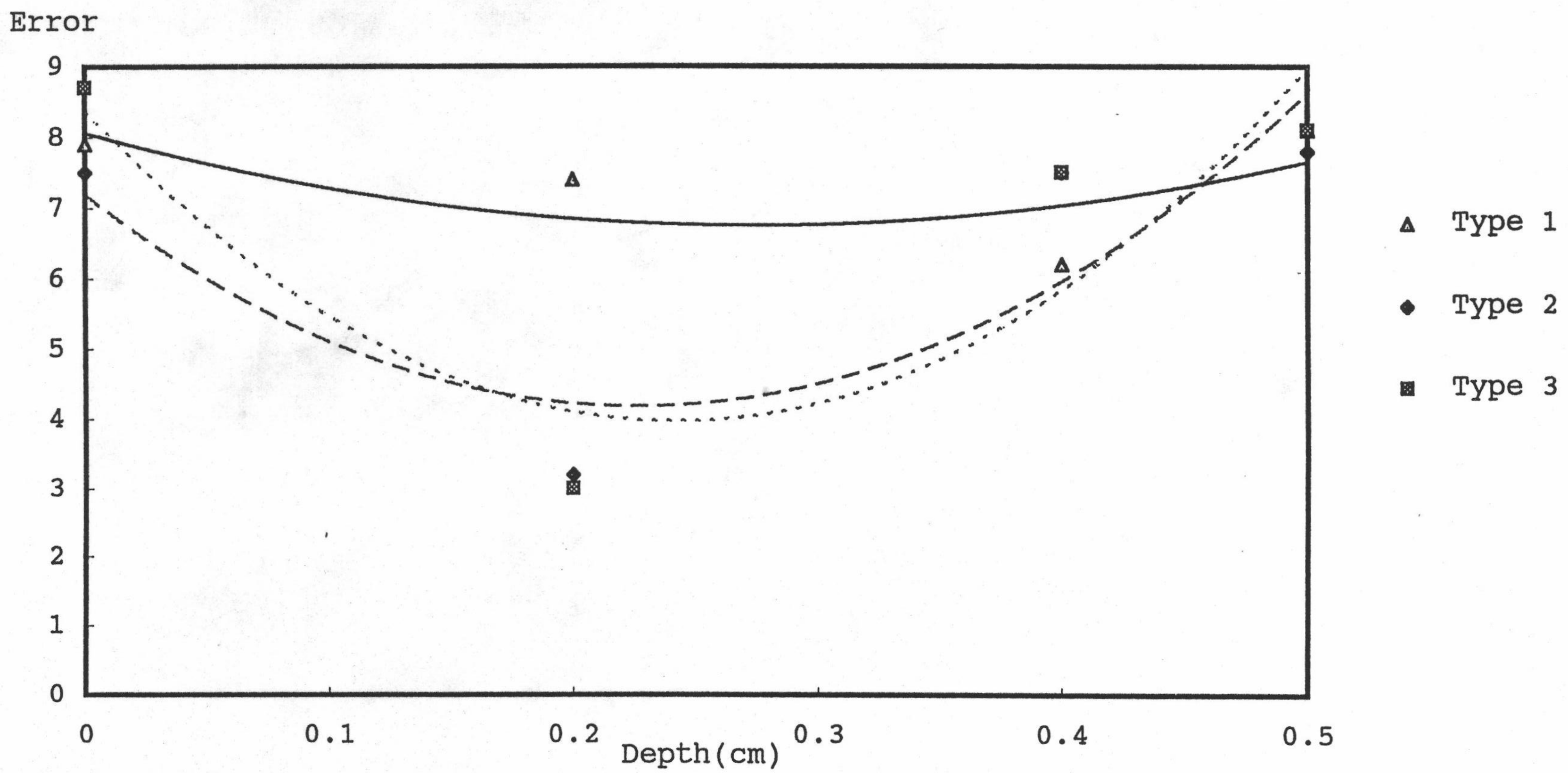

Fig. 4.7 Criteria of optimization based on the absolute value of the difference between the experimental data and the equation for 6 points along the column at 3 hours interval up to 12 hours, as a fuction of WAP concentration for a condition of 50 degree Celcius and 25% RH. Type 1 refers to the linear form of the diffusion coefficient equation, type 2 refers to the power form, and type 3 refer to the exponential form.

Figures 4.8 (a)-(c) show optimization results for 0.2 % WAP mixture for all three types of the dispersion equation. It can be seen that identification of the parameter "a" is fairly good and that the varying condition of the ambient air are not major factors .

For the three types of dispersion equations the identified valued of "a" are presented in Table 4.2

Table 4.2 Averaged Results of optimization of parameter "a" for the three equation types and for three WAP concentrations.

WAP concentration	0%	0.20%	0.40%	0.50%
Type 1	0.30	0.30	0.35	0.30
Type 2	0.50	0.60	0.80	0.75
Type 3	0.06	0.06	0.08	0.07

It can be seen in the type 1 form of equation there is much consistency in the optimized value of "a" over types 2 and 3. , In addition the optimization criteria of type 1 and type 2 equations are the most favored .

It can be said that under the conditions of the experiments conducted, the type 1 equation described by $D_r = am + (1-a)$ is the most appropriate to explain the

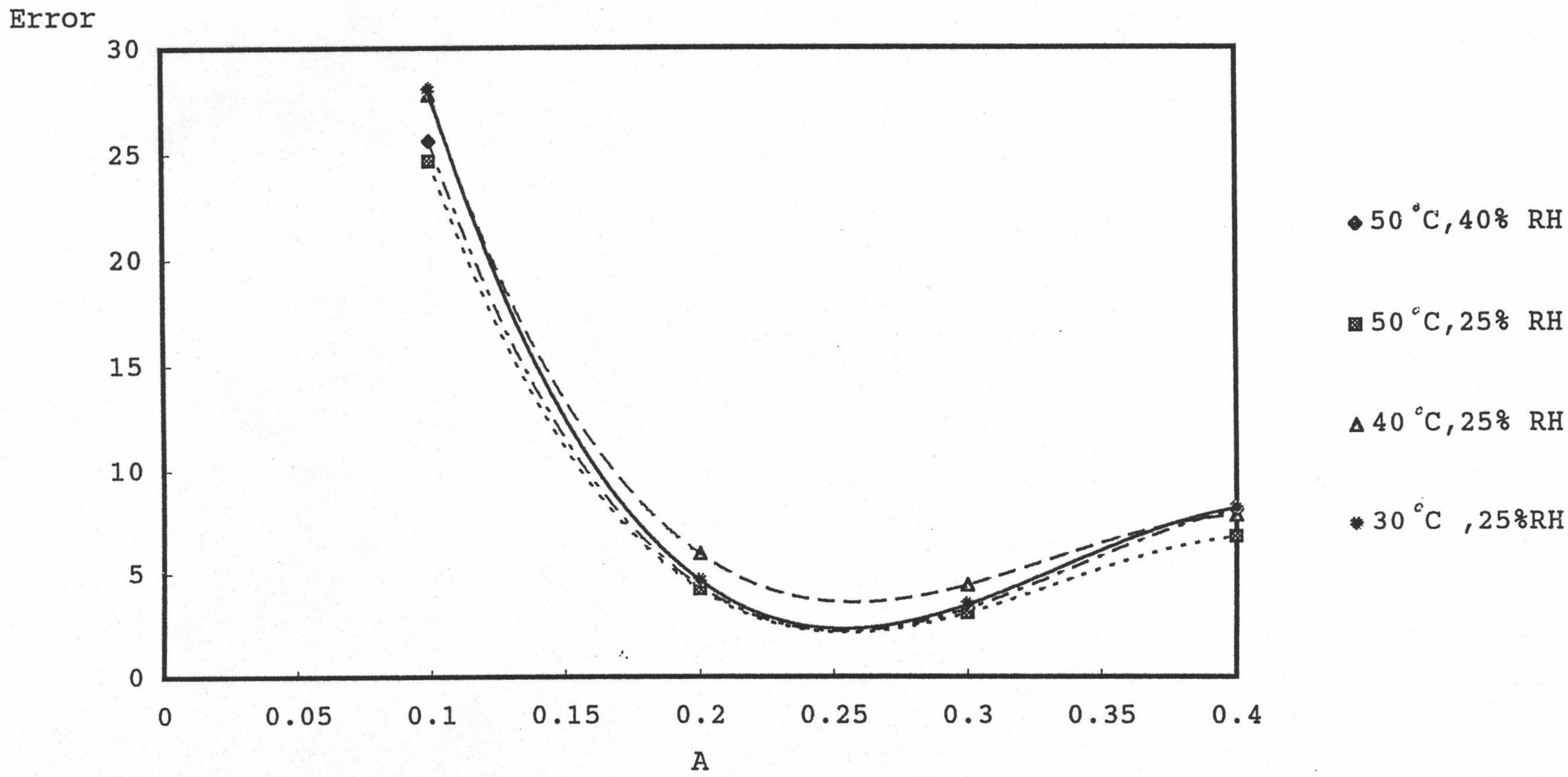

Fig. 4.8 (a) Identification results for parameter a for type 1 dispersion coefficient relation for experiments with sand containing 0.2% WAP.

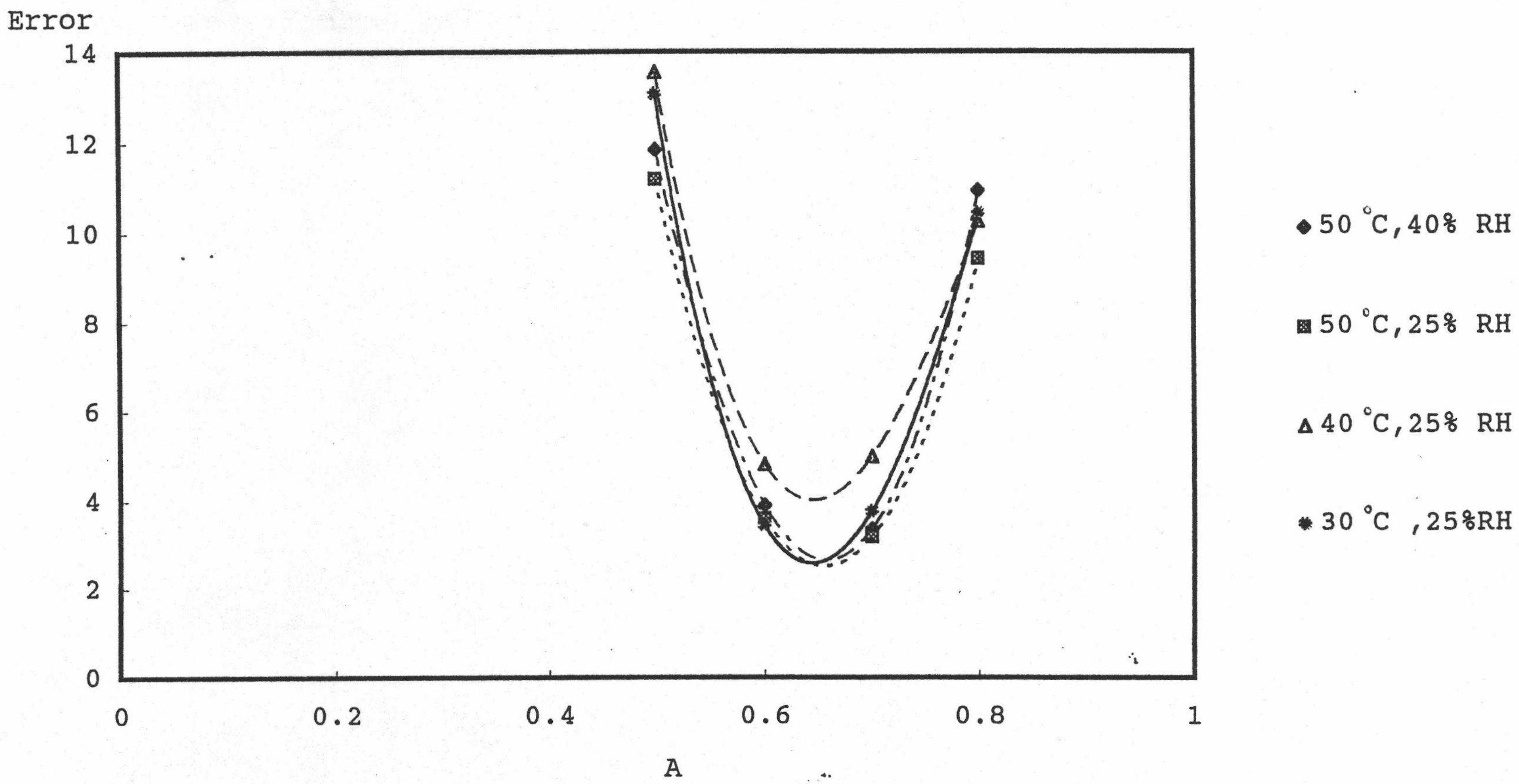

Fig. 4.8 (b) Identification results for parameter a for type 2 dispersion coefficient relation for experiments with sand containing 0.2% WAP.

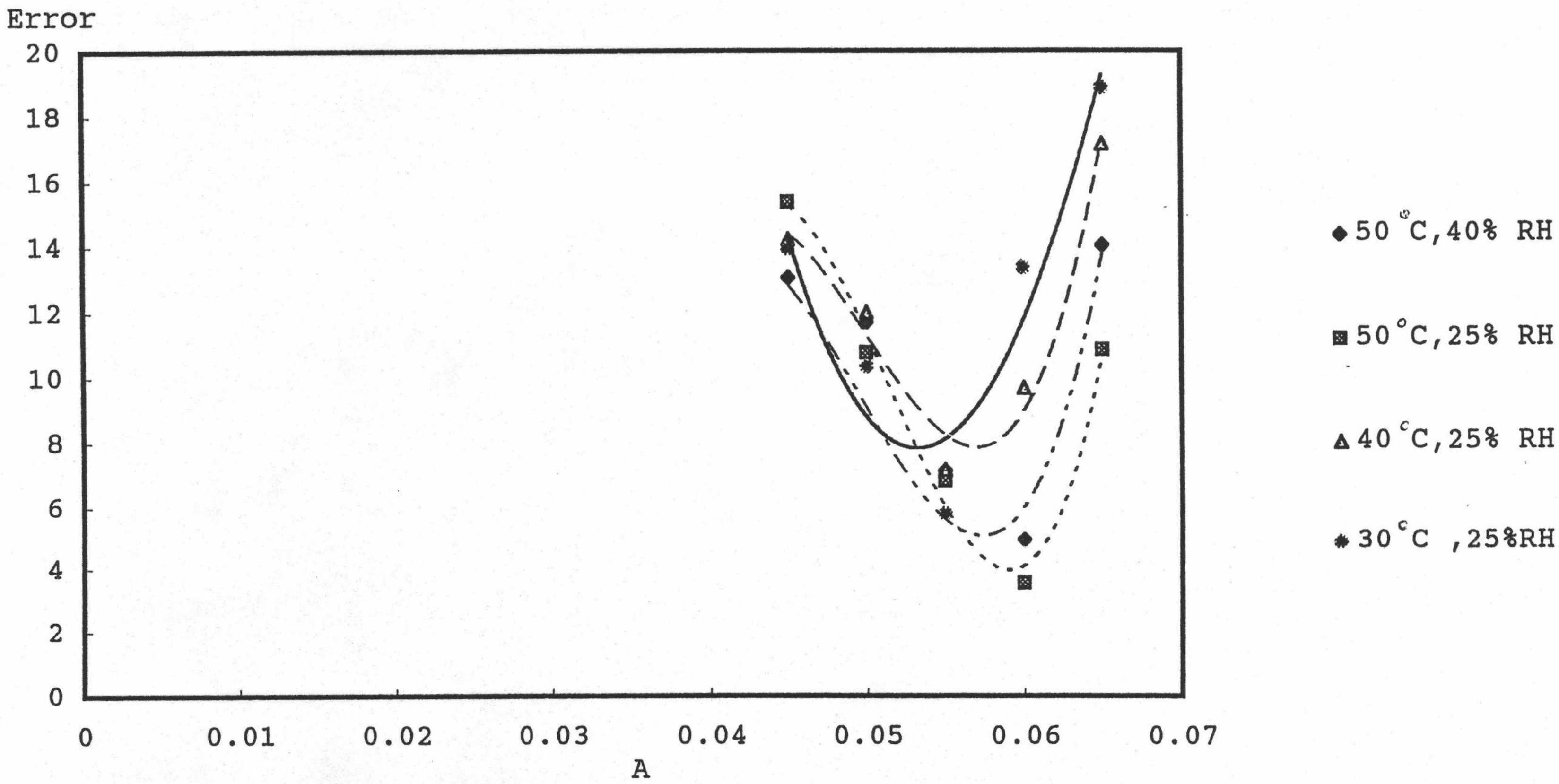

Fig. 4.8 (c) Identification results for parameter a for type 3 dispersion coefficient relation for experiments with sand containing 0.2% WAP.

mass transfer phenomena occurring in the sand column. Furthermore it was found that a value of "a" in the neighborhood of 0.3 explain to a certain extent the mass transfer phenomena occurring.