UNIVERSITY OF JORDAN

Faculty Of Graduate Studies

OPTIMUM DESIGN FOR OVERHANG AND EGGCRATE SHADING DEVICES IN JORDAN

عميد كلية الدراسات العليا

BY:

RAJAB KHALEEL IBRAHEEM

SUPERVISOR

DR : ALI BADRAN

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COMMITEE MEMBERS	SIGNATURE
Dr.Ali Badran Mechanical Engineering Department University of Jordan.	Chairman of Committee
Prof. Mohammed AL Saad Mechanical Engineering Department University of Jordan.	Member of Committee M.A.Alsaad
Dr. Mohammed Hamdan. Mechanical Engineering Department University of Jordan.	Member of Committee

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Abstract

The optimum design of window overhang is carried out to regulate the solar gain through windows and fit the heating and air conditioning needs of a building. In order to achieve this goal usually an overhang is designed to shade the window during summer months while leaving it unshaded during winter. The average daily insolations is calculated with and without an overhang for different azimuth angles for a certain location. Calculations are also made for summer and winter insolations, summer and winter performances of overhangs, and the same procedure is followed to obtain the optimum design of an eggcrate shading device, that is sometimes used to reduce the solar gain through windows.

This work is conducted with special application to weather data of Amman, Jordan, for windows of different azimuth angles in different months of the year. The objective is to obtain the optimum overhang length relative to window height and depth of eggcrate shading devices.

It is found that it is possible to select the optimum overhang ratio for a given direction. The same thing is possible for selecting depth of eggcrate for a given direction, using the optimum design curves. These curves contain summer and winter performances against overhang ratio for overhang and against depth of eggcrate for eggcrate shading devices.

Chapter 1
Introduction

To minimize energy usage for heating and air conditioning, it is recommended to maximize the net building solar energy gains in winter and minimize them in summer.

The external wall of building acts as an energy receiver which admits (directly or indirectly), a large fraction of incident solar radiation to the inside of the building. The major part of the wall that admits this radiation is the window and it is necessary to shade it in summer and leave it unshaded in winter. Shading is usually achieved by using some types of shading devices, as shown in fig(1.1). Some of these shading devices are installed vertically on the wall as shown in fig(1.1a) or horizontally, in which case it is called an overhang, as shown in fig(1.1b).

An overhang is used to decrease the beam radiation during summer and it must be designed to leave the wall unshaded during winter, Also an overhang reduces the diffuse radiation on the wall in summer and winter.

A combination of horizontal and vertical devices form an eggcrate type shading system as shown in fig(1.1c). This is often used in the architectural design of building facades. Such shading devices are used with passive heating and air -conditioning to reduce gains during times

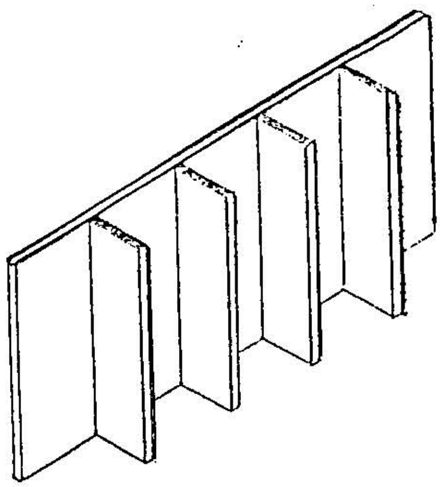
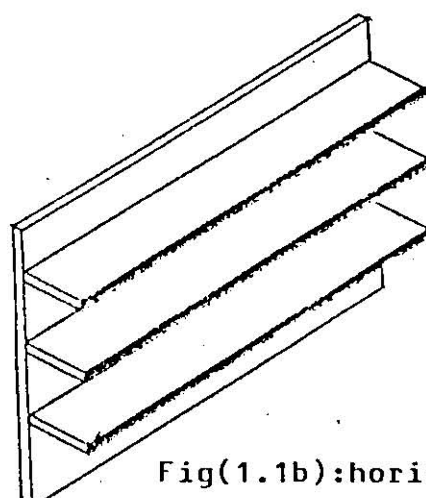
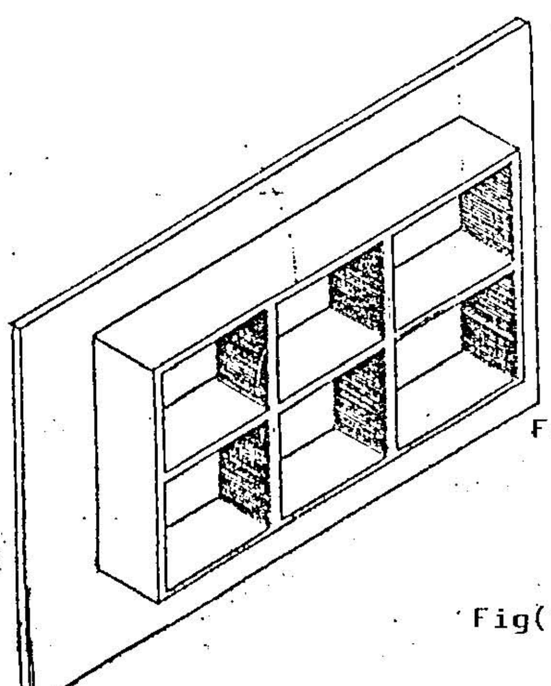


Fig (1.1a): Vertical shading device



Fig(1.1b):horizontal shading device



Fig(1.1c)Eggcrate shading device

Fig(1.1)Types of shading

when heat is not required.

Although the design of shading devices is usually accomplished by using methods achieved by devices such as Olgyay's circular dials [1], and mazria's calculators [2], however only direct beam radiation is considered in those methods.

For a precise calculation of solar gains and loads through the window it is necessary to estimate carefully diffuse and reflected radiation; Liu and Jordan [3], suggested a method to compute total average radiation on a vertical unshaded surface facing the equator. They assumed an isotropic sky diffuse (i.e, uninformly distributed over the sky), and ground reflected radiation.

Klein [4], extended the previous work of Liu and Jordan to obtain the average daily insolation on an arbitrary oriented tilted surface. Klein's method is used because of its relative simplicity since it requires only the knowledge of average daily insolation on a horizontal plane for each calendar month.

Utzinger and Klein [5], presented a method of estimating the monthly average daily radiation on vertical receivers shaded by overhangs. This method is quiet general, in addition it does require the use of numerical integration. Robert and Jones [6], presented a method for calculation of monthly average daily radiation on overhang shaded windows of arbitrary azimuth.

This method is an extension to an arbitrary orientation of the method of Liu and Jordan [3] and of Klein [4] for estimating the radiation on tilted surfaces.

Yanda and Jones [7], presented a method for calculating monthly average radiation on vertical surface facing the equator with an overhang of finite lateral width and this method was an extension to that presented by Robert and Jones[6] for overhang of infinite lateral extent.

Giovanni and Barozzi [8], presented an analytical numerical method to estimate the shading effect of eggcrate shading device on vertical windows of arbitrary azimuthal orientation. The effect of reflection from eggcrate walls is accounted for in the analysis; daily and monthly average solar radiation can be determined by this method.

Based on the previous work done by others and especially that of Robert and Jones[6], whom presented a method of calculation of monthly average daily radiation on overhang shaded windows of arbitrary azimuth, this present work is carried out. In this work the total radiation on the window is calculated taking into account two cases:i) The window is shaded by overhang and ii) The window is unshaded.

The method used is that of Robert and Jones [6] with new application to summer and winter performances and with a special application to the conditions of a certain locality, that is Amman, Jordan. Total summer and winter radiation on unshaded and shaded windows also summer and winter performances of the overhang are also calculated.

The curves which contain summer and winter performances with overhang ratio(i.e. the ratio between the length of overhang to window height) are plotted to help in selecting the optimum overhang ratio. Also, using the method of Giovanni and Barozzi [8] an estimate is made for the total radiation on a window unshaded and shaded by an eggcrate. Thereby the suitable depth of eggcrate for any window direction is obtained.

Also the curves, which contain summer and winter performances against depth of eggcrate are plotted to help in selecting the optimum depth of eggcrate for any direction.

This work is divided into four chapters, for which this, introduction is first. The next chapter (chapter2) includes theoretical analysis where the method of Robert and Jones [6] and the method of Giovanni and Barozzi [8] and other method are illustrated . These methods show how to calculate the total radiation on unshaded and shaded window by overhang and eggcrate.

The results which form the optimum design curves for overhang and eggcrate for different directions are in chapter 3. Tables which contain total radiation on unshaded and shaded window by overhang and eggcrate are included in this chapter.

Discussion and conclusions of the results are contained in chapter4.

Chapter 2
Theoretical analysis

In this chapter, complete analysis for shading is presented, the purpose of the analysis is to present a method for calculation the total insolation on a window or a wall shaded by i) An overhang and ii) An eggcrate .The methods presentd are:

i) Method of Robert and Jones[6], who presented a method for the calculation of monthly average daily radiation on overhang shaded windows of arbitrary azimuth.

ii) Method of Giovanni and Barozzi[8], who presented an analytical method to estimate the shading effect of eggcrate shading device on vertical windows of arbitrary azimuthal orientation. The effect of reflection from eggcrate walls is accounted for in the analysis. Daily and monthly average solar radiation can be determined by this method. However a method for the calculation of the average daily radiation on an arbitrary surface is presented first.

2.1 Estimation of the average daily radiation on an arbitrary surface

In this section, the method of Klein [4], for the estimation of the average daily radiation on an arbitrary surface is reviewed for easy reference .One of the essential requirments of this method is to obtain the average daily radiation, $\overline{H}$, on a horizontal surface.

$\overline{H}$ is a measured value for Amman city and it can be found in Ref[9]. Once the value of $\overline{H}$ is known, a fraction $\overline{K_t}$ is defined, which is the ratio of the radiation $\overline{H}$ reaching the surface to the mean daily extraterrestrial radiation, $\overline{H_o}$ on the same surface.

$$\overline{K_t} = \overline{H} / \overline{H_o} \quad \text{.......} \quad (2.1)$$

$\overline{H_o}$ may be calculated from Klien[4]

$$\overline{H}_o = \frac{1}{(m_1 - m_2)} \sum_{n=m_1}^{m2} (H_o)_n \quad \text{.......} \quad (2.2)$$

where m_1 and m_2 are the days of the year at the start and the end of the month, respectively, and $(H_0)_n$ is the extraterrestrial radiation on the surface on the day n of the year $(H_0)_n$. is given by[4]:-

$$(H_o)_n = 24/\pi \ I_{sc}[1+0.033 \cos (360n/365)]*$$

$$[\cos \phi \cos \delta \sin \omega_s + (\omega_s 2\pi/360) \sin \phi \sin\delta] \text{.......} (2.3)$$

Where I_{sc} is the solar constant, n the day of the year, ϕ is the latitude, δ is the solar declination and ω_s is the sunset hour angle.

$\overline{H}_0$ can be conveniently estimated from eq(2.3) by selecting for each month, the day n of the year for which the daily extraterrestrial radiation is nearly the same as the monthly mean value.The value of n and the corresponding value of δ are given in table (A.1) in the Appendix A.

Using the 16th day at each month can lead to small errors in $\overline{H}_o$, particularly for June and December. The value of the solar constant, I_{sc}, included in the eq(2.3) obtained from[4] is 4871 KJ hr^{-1} m^{-2} This is equivalent to the commonly known value of 1353 w/m^2.

The average daily radiation on a tilted $\overline{H}_t$, can be expressed as:

$$\overline{H}_t = \overline{R}\ \overline{H} = \overline{R}\ \overline{K}_t\ \overline{H}_o \quad \text{......(2.4)}$$

where $\overline{R}$ is defined as the ratio of the daily average radiation on a tilted surface to that on horizontal surface for each month. $\overline{R}$ can be estimated by individually considering the beam, diffuse and reflected components of the radiation incident on the tilted surface. Assuming diffuse and reflected radiation to be isotrpic, Liu and Jordan[3] proposed that $\overline{R}$ can be expressed as:

$$\overline{R} = (1-\overline{H}_d/\overline{H})\overline{R}_b+(\overline{H}_d/\overline{H})(1+\cos\beta)/2+\rho(1-\cos\beta)/2 \quad \text{......(2.5)}$$

Where $\overline{H}_d$ is the monthly average daily diffuse radiation(i.e. the amount of daily diffuse radiation averaged over one month), $\overline{R}_b$ is the ratio of the average beam radiation on the tilted surface to that on a horizontal, (it will be shown later how to calculate $\overline{R}_b$) and ρ is the ground reflectance. Liu and Jordan[3] suggest that ρ varies from 0.2 to

0.7 depending upon the ground conditions which may rang from green glass to snow cover, and β is the tilt of the surface.

Since measurements of $\overline{H}_d$, the monthly average daily diffuse radiation are rarely available, $\overline{H}_d$ should be estimated from measurements of the average daily total radiation. In a number of investigations, it was found that the diffuse radiation fraction, $\overline{H}_d / \overline{H}$, is a function of $\overline{K}_t$ .The relationship reported by Liu and Jordan[3] given by:

$$\overline{H}_d / \overline{H} = 1.39 - 4.027\overline{K}_t + 5.53\overline{K}_t^{\,2} - 3.108\,\overline{K}_t^{\,3} \qquad \text{...(2.6)}$$

And the relationship reported by page[10] given by:

$$\overline{H}_d / \overline{H} = 1 - 1.13\,\overline{K}_t \qquad (2.7)$$

Collares-pereira and Rabl[10] found that $\overline{H}_d/\overline{H}$ can be expressed in terms of the Sunset hour angle of the mean day of the month. An equation for $\overline{H}_d/\overline{H}$ (with ω_s in degrees) is:

$$\overline{H}_d/\overline{H} = 0.775 + 0.00653(\omega_s - 90) - [0.505 + 0.00455(\omega_s - 90)]^* \cos[115\,\overline{K}_t - 1.3] \qquad (\ 2.8)$$

2.1.1 Estimation of $\overline{R}_b$

$\overline{R}_b$ is a function of transmittance of the atmosphere which depends upon the atmospheric cloudiness, water vapor and particulate concentration.

Liu and Jordan[3] suggested that $\overline{R}_b$ can be estimated from the ratio of extraterrestrial radiation on the tilted surface to that on a horizontal surface for a month.

$\overline{R}_b$ can be expressed as:

$$\overline{R}b = \{ [\cos\beta \sin\delta \sin\phi]\pi/180 [\omega_{ss} - \omega_{sr}] - [\sin\delta \cos\phi \sin\beta \cos\gamma] \pi/180 [\omega_{ss} - \omega_{sr}] + [\cos\phi \cos\delta \cos\beta][\sin\omega_{ss} - \sin\omega_{sr}] + [\cos\delta \cos\gamma \sin\phi \sin\beta] [\sin\omega_{ss} - \sin\omega_{sr}] - [\cos\delta \sin\beta \sin\gamma] [\cos\omega_{ss} - \cos\omega_{sr}] \} \{ 2 [\cos\phi \cos\delta \sin\omega_s + (\pi/180)\omega_s \sin\phi \sin\delta] \} \quad (2.9)$$

where γ is the surface azimuth angle, i.e. the deviation of the normal to the surface from the local meridan, the zero value being due South, East is negative, and West is positive. ω_{sr} and ω_{ss} are the sunrise and sunset hour angle on the tilted surface, given by[3]:

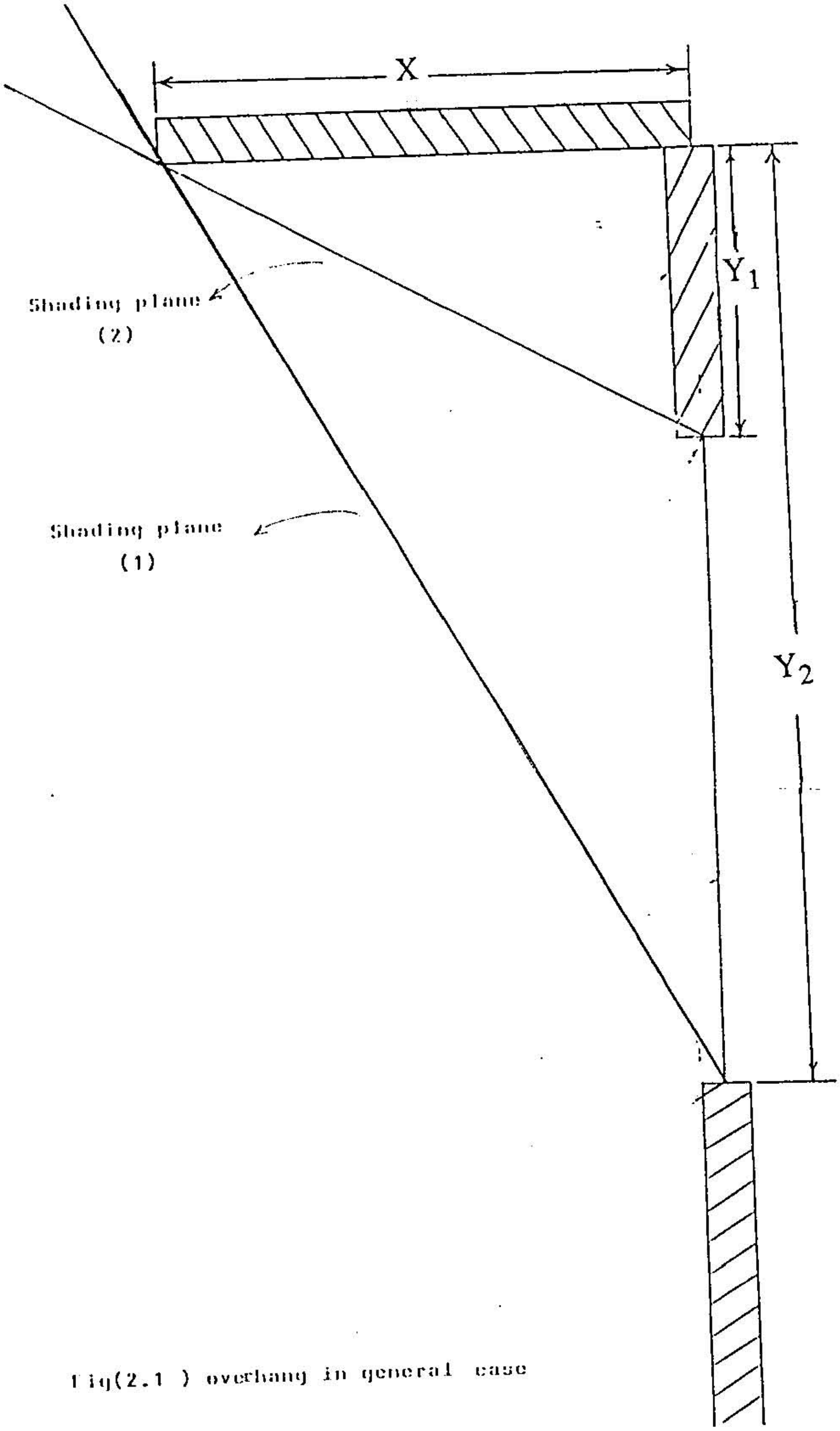
for $\gamma < 0.0$

$$\omega_{sr} = -\min[\omega_s, \arccos[(AB+\sqrt{A^2-B^2+1})/(A^2+1)] \quad (2.10)$$

$$\omega_{ss} = \min[\omega_s, \arccos[(AB-\sqrt{A^2-B^2+1})/(A^2+1)] \quad (2.11)$$

if $\gamma > 0.0$

$$\omega_{sr} = -\min[\omega_s, \arccos[(AB-\sqrt{A^2-B^2+1})/(A^2+1)] \quad (2.12)$$



Fig(2.1) overhang in general case

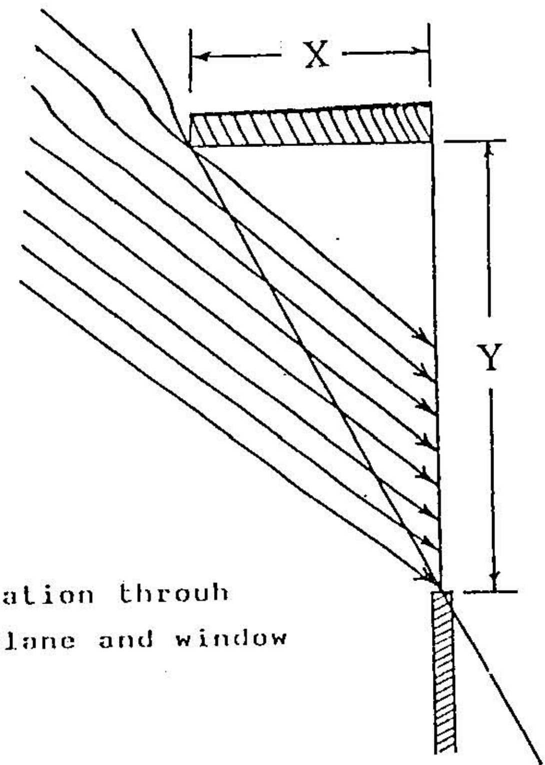


Fig (2.3) Beam radiation throuh shading plane and window

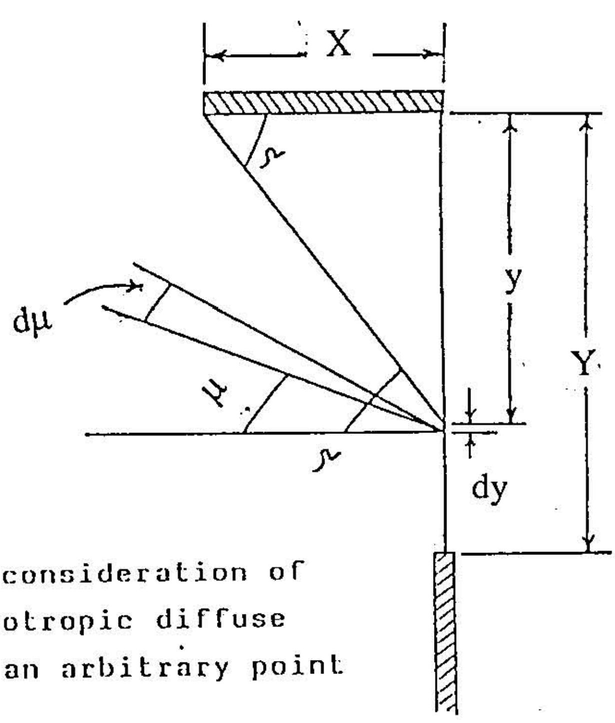
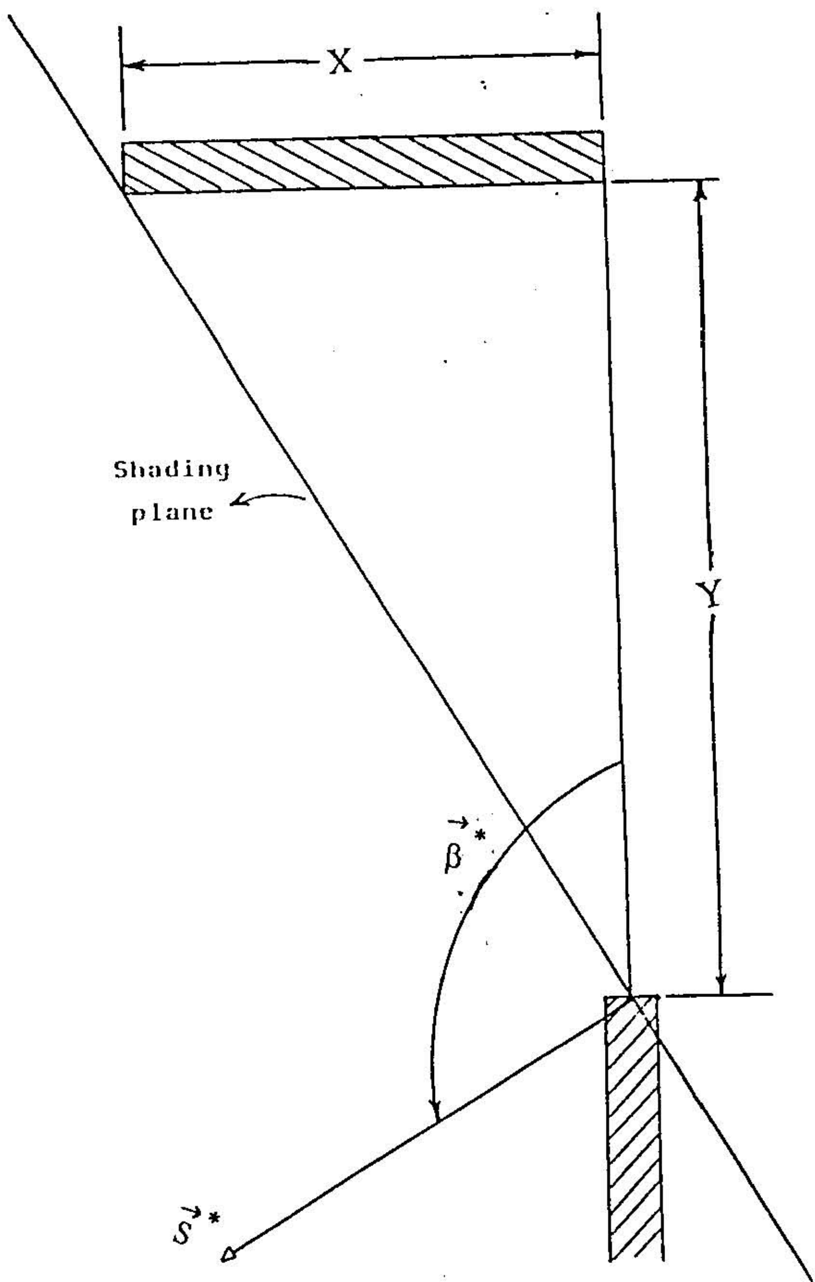


Fig (2.4) Geometry of consideration of shading of isotropic diffuse radiation of an arbitrary point on window



Fig(2.2)Geometry of overhang and window illustrating
the shading plane and its normal

A special case is assumed where the overhang extends directely at the top of the window (i.e the distance Y_2 is zero) as shown in Fig(2.2). The shading plane is defined as the plane extending between the leading edge of the overhang and the bottom edge of the window.

The normal $\vec{S}^*$ to the shading plane points into the ground with a tilt angle $\beta^* > 90°$ which is given by :

$$\beta^* = 180 - \tan^{-1}(1/Z) \quad (2.16)$$

Where Z is termed as the overhang ratio and is defined by

$$Z = X/Y \quad (2.17)$$

The total radiation on a shaded window can be divided into three parts:

2.2.1 Beam radiation:

In order to estimate the beam radiation on a shaded window, consider that the sun is below the shading plane, so that ,it shines at least on a portion of the window plane. Let the sunrise and sunset hour angles for the shading plane be designated by ω_{sr}^* and ω_{ss}^*, respectively.

Therefore, the radiation on the shading plane is simply that on a surface of tilt β^* and azimuth γ.

The result of previous section hold without change. Therefore, as shown in Fig(2.3), the beam radiation on the section of interest of the shading plane per unit width is the same radiation on the shaded window per unit width. Consequently the average beam radiation density on the shaded window is the same as that through the shaded plane, multiplied by the geometrical factor $\sqrt{X^2 + Y^2}$

Since, we deal with dimensionless values with respect to Y, the geometrical factor becomes:

$$\frac{\sqrt{X^2+Y^2}}{Y} = \sqrt{\frac{X^2}{Y^2}+\frac{Y^2}{Y^2}} = \sqrt{1 + Z^2} \quad \text{.........................} \quad (2.18)$$

2.2.2 Diffuse radiation:

The basic assumption here is that the radiation affecting the window is isotropic diffuse from the sky.

To estimate the diffuse radiation on shaded window. as shown in Fig(2.4), assume an arbitrary point of the window, at distance y from the top of the window. Due to the presence of the overhang, a portion of isotropic diffuse solar radiation from the sky is shaded.Applying lambert's cosine law in cylindrical coordinates Ref[6], the fraction of this radiation which arrives at a point y from the differential angle dμ at an angle of incidence μ is given by:

$$df = 1/2 \cos\mu \, d\mu \quad \text{...} \quad (2.19)$$

Integration from μ =0.0 to Ω yields the total unshaded fraction incident of y which is $f = 1/2 \sin\Omega$

Therefore the fraction of diffuse radiation which the entire window receives which is given from Ref[6] is given by:

$$\frac{1}{Y}\int_{y=0}^{Y} f\,dy = \frac{1}{2y}\int_{0}^{Y}\sin\Omega\,dy$$

$$= \frac{1}{2}Z\left(\frac{1}{\cos\left\{\tan^{-1}\left(\frac{1}{Z}\right)\right\}} - 1\right) \quad \text{.........................(2.20)}$$

Since an unshaded vertical window would receive only one-half the hemispherical diffuse solar radiation from sky,(because the view factor to the sky is equall to (1+cos β)/2, for vertical surface (β=90)), in this case the view factor =1/2).

therefore, the fraction which the shaded window receives is given by[6]:

$$S_d^* = Z\left(\frac{1}{\cos\{\tan^{-1}(1/Z)\}} -1\right) \quad \text{...................................(2.21)}$$

2.2.3 Reflected radiation:

The basic assumption here is that the reflected radiation comes basically from the horizontal plane made by the ground. To estimate the reflected radiation on shaded window ,the radiation reflected from the ground is assumed to be isotropic.

The average daily reflected radiation on the window is $\frac{1}{2}\overline{H}\rho_1$ where ρ_1 is the reflectance of the ground. Here the reflection or shading of radiation by the window and its surrounding wall is neglected. Under these assumptions the reflected radiation incident on the overhang is $\frac{1}{2}\overline{H}\rho_1$ Assume an element of the overhang of width dx. Thus the daily energy reflcted from that element, and unit lateral extent is given by $\frac{1}{2}\overline{H}\rho_1\rho_2\,dx$ where ρ_2 is the overhang reflectance.

Using the geometry shown in Fig(2.5), a method analogous to that used for diffuse and beam radiation the yields the following geometrical factor for reflected radiation, F_d*, which is given from Ref[6] given by:

$$F_d{}^* = \frac{1}{2}(1+Z-\frac{1}{\sin\{\tan^{-1}(1/Z)\}}) \quad \text{.........................(2.22)}$$

Now, the total radiation on shaded window is estimated by combining the beam, diffuse and reflected radiation gives the total average radiation of shaded window during an average day is:

$$H^* = H_b{}^* + H_d{}^* + H_r{}^* \quad \text{......................................(2.23)}$$

Where H^*: total average radiation of shaded window.

$H_b{}^*$: beam radiation on shaded window.

$H_d{}^*$: difusse radiation on shaded window.

$H_r{}^*$: reflected radiation on shaded window.

and

$$H_b{}^* = (1+z^2)^{\frac{1}{2}} R_b(\beta^*)\,\overline{H}_b \quad \text{.................................(2.24)}$$

$$H_d{}^* = \frac{1}{2} S_d{}^*\,\overline{H}_d{}^* \quad \text{.................................(2.25)}$$

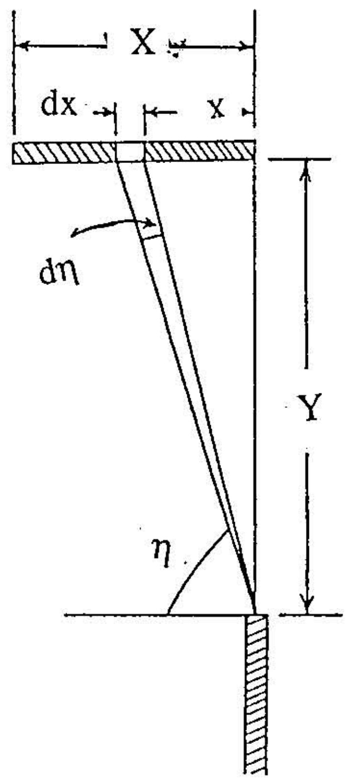


Fig (2.5) Geometry of radiation reflected from overhang

$$H_r^* = \frac{1}{2} \overline{H} \rho_1 [1+\rho_2 F_d^*] \quad \text{......................................(2.26)}$$

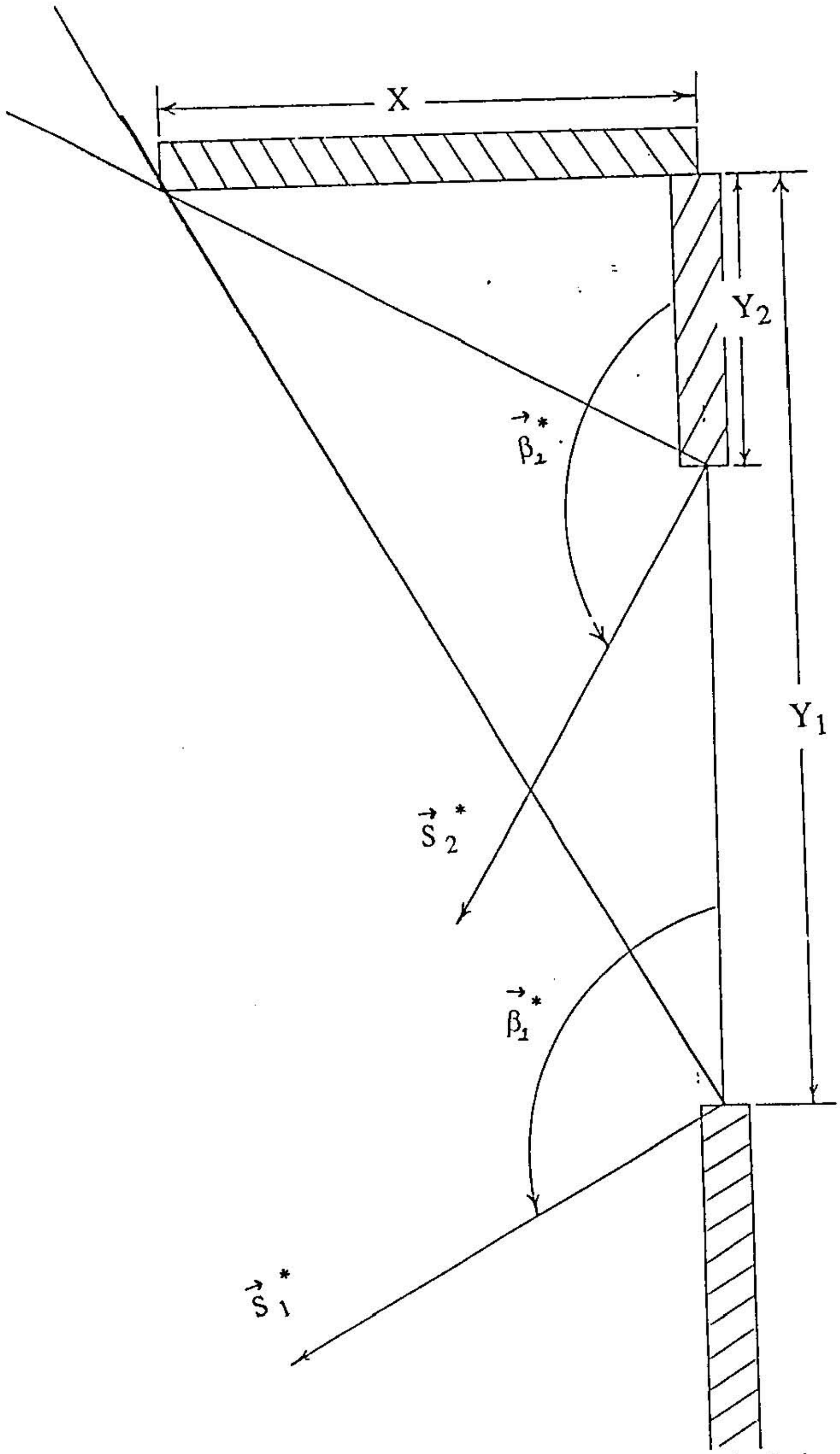
Now one can estimate the total radiation on shaded window by overhang in the general case,in which the overhang is separated by a section of vertical wall from the window as shown in Fig(2.6).

The daily energy per unit width W incident on the entire section of height Y_1 is $Y_1 \overline{H}^*(\beta_1^*)$ where the parenthesis mean only the dependence of $\overline{H}^*$ upon β_1^*. Also the daily energy per unit width incident on the separating wallsection of height Y_2 is $Y_2 \overline{H}^*(\beta^*_2)$. Therefore the average daily irradiation of window of height (Y_1-Y_2) is given by:

$$\overline{H}^*(\beta^*_1,\beta^*_2) =(Y_1 \overline{H}^*(\beta^*_1) - Y_2 \ \overline{H} \ (\beta^*_2)) \ / \ (Y_1-Y_2) \quad \text{..................(2.27)}$$

2.3 Eggcrate structures on vertical windows

Eggcrate structures are widely used both as shading system and as architectural elements on large building facades. These structures may be square, horizontal and vertical rectangular geometries. Following the analytical numerical method of Barozzi and Grossa[8], total monthly average radiation is calculated on unshaded and shaded windows with eggcrate structures for different azimuth angles for the city of Amman, [then a summer and winter perfomances which represents some kind of efficiency of eggcrate structure in summer and winter



Fig(2.6) Geometry of overhang separated from top of window are calculated]. The objective of the performance and analysis is to establish optimum design for eggcrate structure for a given wall orientation in the city of Amman.

2.3.1 General description for eggcrate device:-

The geometry of the shaded window is shown in Fig(2.7). Relevant length parameters are the receiver heigh h', width w' and projection depth p'.

Geometrical similarity is achieved for equal ratios of those quantities relative to characteristic length of the window, which is defined by:

$$L' = \sqrt{w'h'} = \sqrt{A} \quad (2.28)$$

Relative hight is defined by:

$$h = h'/L' \quad (2.29)$$

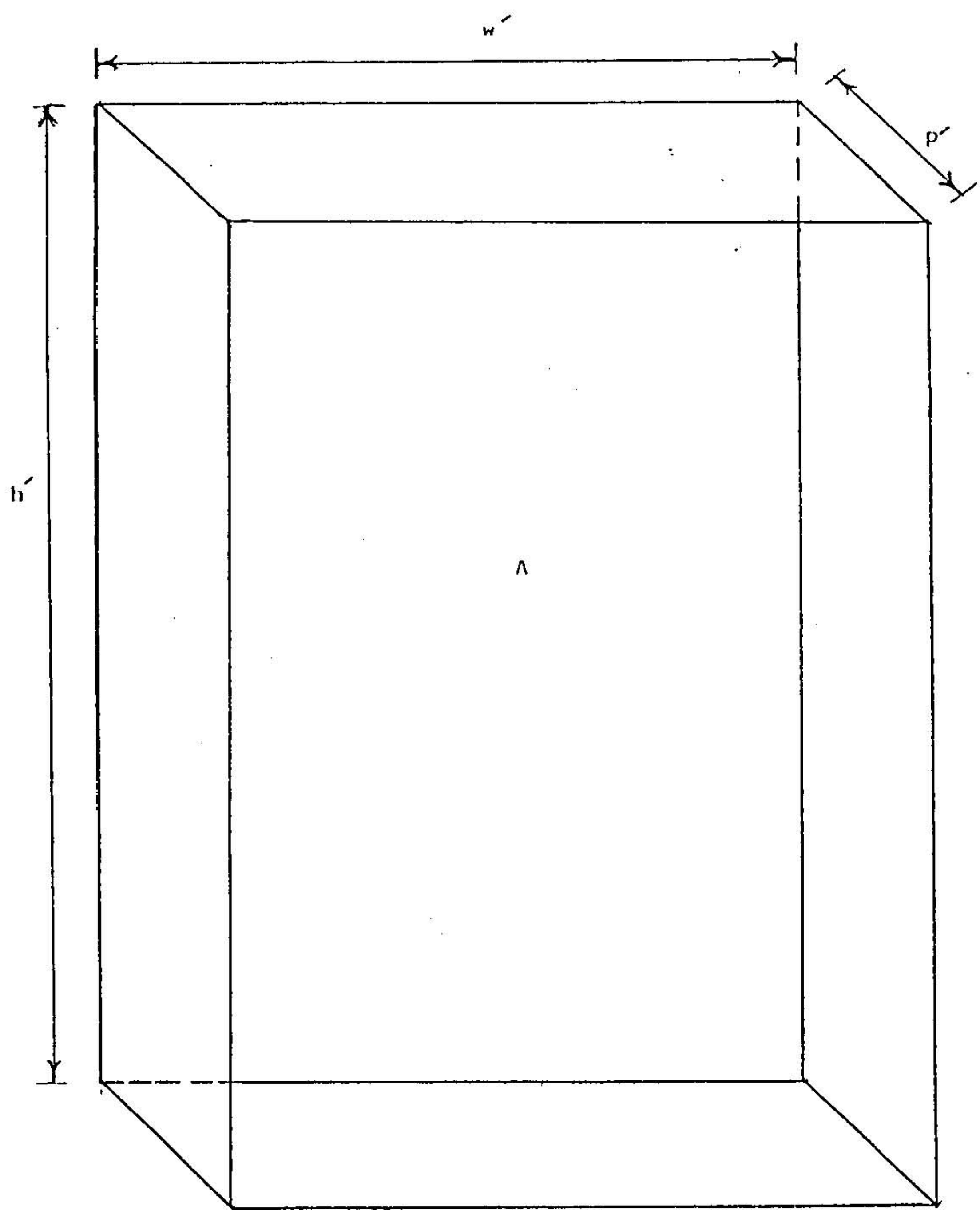
and relative width is defined by:

$$w = w'/L' \quad (2.30)$$

and relative depth is defined by:

$$p = p'/L' \quad (2.31)$$

Due to the choice of the characteristic length, the non dimensionl receiver area is untity because



Fig(2.7) Eggcrate shading system and window geometry

$$A = \sqrt{h.w} = \sqrt{\frac{h'}{L'}\frac{w'}{L'}} = \frac{\sqrt{h'w'}}{\sqrt{L'^2}}$$

$$A = \frac{\sqrt{h'w'}}{L'} = \frac{\sqrt{h'w'}}{\sqrt{h'w'}} = 1 \quad \text{.......................................(2.32)}$$

And this is particularly useful when comparing the shading effects on windows of different geometry.

2.3.2 Estimation of average daily radiation on a receiver shaded by eggcrate:-

Taking the total mean radiation over a shaded window ,I_t, as the total solar radiation on the window divided by window area, one can split ,I_t, into four components, namely, direct beem, I_b, sky diffuse ,I_d, ground reflected radiation ,I_g, and one more term accounting for reflected radiation from the shader walls onto the receiver, I_r.

This term ,I_r, in turn is subdivided into three terms, $I_{b,r}$ $I_{d,r}$, $I_{g,r}$ due to the direct, sky-diffuse and ground reflected radiation respectively.

The following relationship therefore holds:-

$$I_t = I_b + I_d + I_g + I_r \quad \text{.......................................(2.33)}$$

where:

$$I_r = I_{b,r} + I_{d,r} + I_{g,r} \quad \text{.......................................(2.34)}$$

The right-hand side terms in eqn(2.32), (2.33) are determined individually, as discussed in the following sections.

The monthly-average daily radiation on a shaded receiver, $H_{t,s}$ is function of the total mean radiation. $H_{t,s}$ is estimated by integration of instantneous radiation over an average day representative of the month under consideration from sunrise to sunset.

The total long-term radiation is then given by:

$$H_{t,s} = \int_{day} I_t dt \quad \text{from sunrise to sunset} \qquad (2.35)$$

The terms in the (rhs) of (2.33) are similarily correlated to $H_{b,s}$, $H_{d,s}$, $H_{g,s}$ and $H_{r,s}$.

Total daily radiation on unshaded receiver H_t and its components H_b, H_d, H_g are detemined by the same procedure. Then the performance with and without shading is compared. When hour by hour perfomance calculations for a system are to be carried out, it may be necessary to start with daily data to estimate hourly values from daily radiation in order to calculate I_b, I_d, I_g and I_r. The method of Barozzi and Grossa requires the knowledge of the values of the above types of radiation on a horizontal surface, that is $I_{b,h}$, $I_{d,h}$, $I_{t,h}$ which are usually measured or to be calculated from daily total radiation.

The relation between hourly and daily total radiation on a horizontal surface, may be obtained by the equation from Collares-

Pereira and Rabl[10].

$$r_t = \frac{I_{t,h}}{H} = \frac{\pi}{24}(a + b\cos\omega)\left\{\frac{(\cos\omega - \cos\omega_s)}{(\sin\omega_s - (2\pi\omega_s/360)\cos\omega_s)}\right\} \quad ..(2.36)$$

The coefficients a and b are given by:

$$a = 0.409 + 0.5016\sin(\omega_s - 60) \quad ....(2.37)$$

$$b = 0.6609 - 0.4767\sin(\omega_s - 60) \quad ....(2.38)$$

Another relation between hourly and daily total radiation on horizontal surface may be obtained by equation of Jain used by Alsaad[11] which is given by:

$$r_t = \frac{1}{\sigma\sqrt{2\pi}}\exp\left(-\frac{(t-12)^2}{2\sigma^2}\right) \quad ....(2.39)$$

Where t is the solar time and σ values related to day length N_0 through a linear correlation of the form :

$$\sigma = a + b\,N_0 \quad ....(2.40)$$

Where a and b are costants.

Alsaad[11] found by the least squares technique that using

a = 0.153 and b = 0.226 gives an excellent fit for the data of Amman, and it can be used for any place in Jordan.

The relation between hourly diffuse and daily diffuse radiation on horizontal surface is given by the equation by Liu and Jordan (1960):

$$r_d = \frac{I_{d,h}}{H_d} = \frac{\pi}{24}\left\{\frac{(\cos\omega - \cos\omega_s)}{(\sin\omega_s - (2\pi\omega_s/360)\cos\omega_s)}\right\} \quad (2.41)$$

Also,

$$I_{t,h} = I_{b,h} + I_{d,h} \quad (2.42)$$

2.3.3 Direct beam radiation:-

This is expressed as:

$$I_b = I_{b,h} \cdot f \cdot \cos\theta / \cos\theta_z \quad (2.43)$$

Where θ and θ_z are defined as incidence angle of solar beam for real and horizontal orientation and f designates the fraction of receiver area impinged on by direct beam radiation . It's exprssed as:

$$f = (h-h_S)(w-w_S) \quad (2.44)$$

Where h_S and w_S are the shaded fraction of h and w as in Fig(2.8). They are given by:

$$h_S = p \tan\alpha / \cos(\gamma_s-\gamma) \quad (2.45)$$

$$w_S = p \tan(\gamma_s-\gamma) \quad (2.46)$$

Where α is the sun altitude, given by:1

$$\sin\alpha = \cos\phi \cos\delta \cos\omega + \sin\phi \sin\delta \quad (2.47)$$

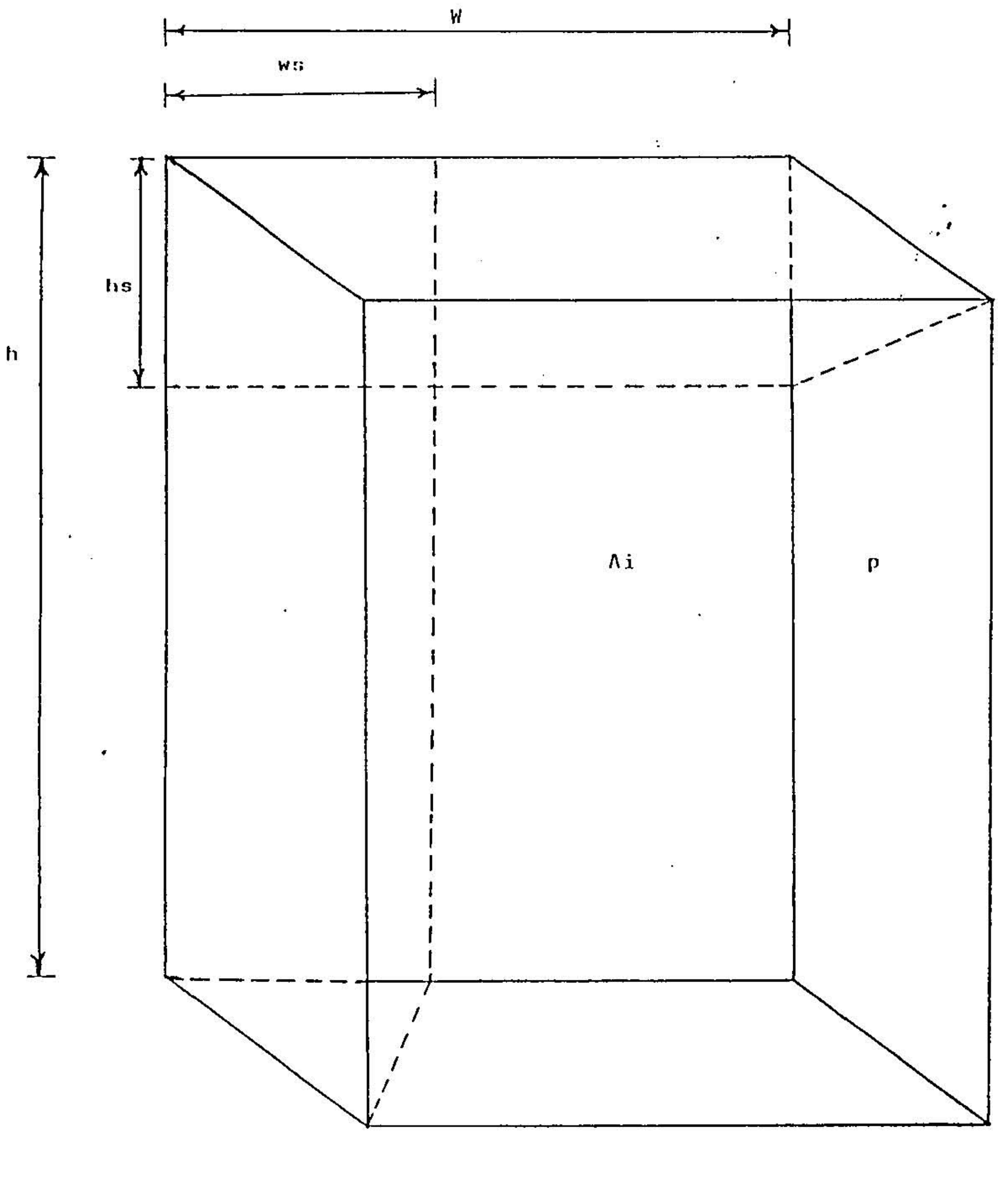


Fig (2.8) Shade geometry of direct beam radiation

2.3.4 Sky diffuse and ground reflected radiation

With the assumption of isotropic diffuse and ground-reflected radiation, I_d, and I_g are given by:

$$I_d = F_{r,s}\ I_{d,h} \qquad \text{.......(2.48)}$$

$$I_g = \rho_g\ F_{r,g}\ I_{t,h} \qquad \text{.......(2.49)}$$

Where ρ_g is ground reflectivily, and $F_{r,s}$ and $F_{r,g}$ are the receiver radiation view factors of the sky and the ground respectively. For the geometry under consideration here, they are equal and can easily be estimated by having the view factors for two opposed, parallel, congruent rectangular areas. This is given by:Ref[8]

$$F_{r,s} = (1/\pi XY)Ln\left[(1+X^2)(1+Y^2)/(1+X^2+Y^2)\right]^{\frac{1}{2}} + Y\sqrt{1+X^2}\ \tan^{-1}(Y/\sqrt{1+Y^2}) + X\sqrt{1+Y^2}\ \tan^{-1}(X/\sqrt{1+Y^2}) + Y\tan^{-1}Y - \tan^{-1}X\,] \qquad \text{.......(2.50)}$$

Where $X = h/p.$ ....(2.51)

$Y = w/p.$ ....(2.52)

2.3.5 Reflected radiation:-

For the sake of easy estimation of I_r components, the enclosure structure shown in Fig(2.7) is assumed to be parallelepiped formed by the eggcrate surfaces, the receiver and ficticious surface at the open side. Following the assumptions mentioned in previous sections, that:

1- Eggcrate surfaces reflect isotropically.

2- The receiver and the open side surfaces have zero reflectivity

3- The Radiant flux reflected by the walls is diffused throughout the enclosure space.

Thus incident solar energy not directly impinging upon the window circulates in the enclosure and is progeressively absorbed by the bounding surfaces.

Now assuming that:

$\phi_b^{(o)}$ is the radiant flux due to direct beam, after the first reflection. (i.e. the radiation on the all area of the reciever)

$\phi_d^{(o)}$ is the radiant flux due to sky- diffuse, after the first reflection.

ϕ_g is the radiant flux due to ground-reflected, after the first reflection.

After the first reflection on the shader walls, they are given[6] by:

$$\phi_b^{(o)} = \sum_{i=1}^{3}(\rho_i \, f_i \, A_i \cos\phi_i) \, I_b \quad \text{......................................(2.53)}$$

$$\phi_d^{(o)} = \sum_{i=1}^{3}(F_{i,s} \, A_i) \, I_{d,h} \quad \text{..(2.54)}$$

$$\phi_g^{(o)} = \sum_{2}^{4}(F_{i,g} \, A_i) \, I_{t,h} \quad \text{...(2.55)}$$

Where the index i specifies eggcrate surfaces as depicted in Fig(2.9).

ρ_i : designates reflectivity.

A_i : area.

f_i : irradiated area fraction(i.e. the fraction of the irradiated area to the total area of the reciever).

θ_i : incidence angle

$F_{i,g}$: view factor of the surface to ground.

$F_{i,s}$: view factor of the surface to sky.

Some possible shade configurations of direct beam radiation are presented in Fig(2.10). The top side of the eggcrate is always shaded and not shown in the figure.

Eggcrate shade can take ten different geometrical configurations depending the intantaneous value of h_S,w_S and γ_S

Expression for f_i are given for the five cases where

$\gamma_S > \gamma$ (f3 = 0.0) shown in Fig(2.10)

The term d_S, d_S are introduced as follows:

d_S: designates the shaded fraction of p due to the projection of the horizontal uper edge over the lower side of the eggcrate.

d_S: is shade fraction of p due to the projection of vertical right (or left) edge over the left(right) side of eggcrate.

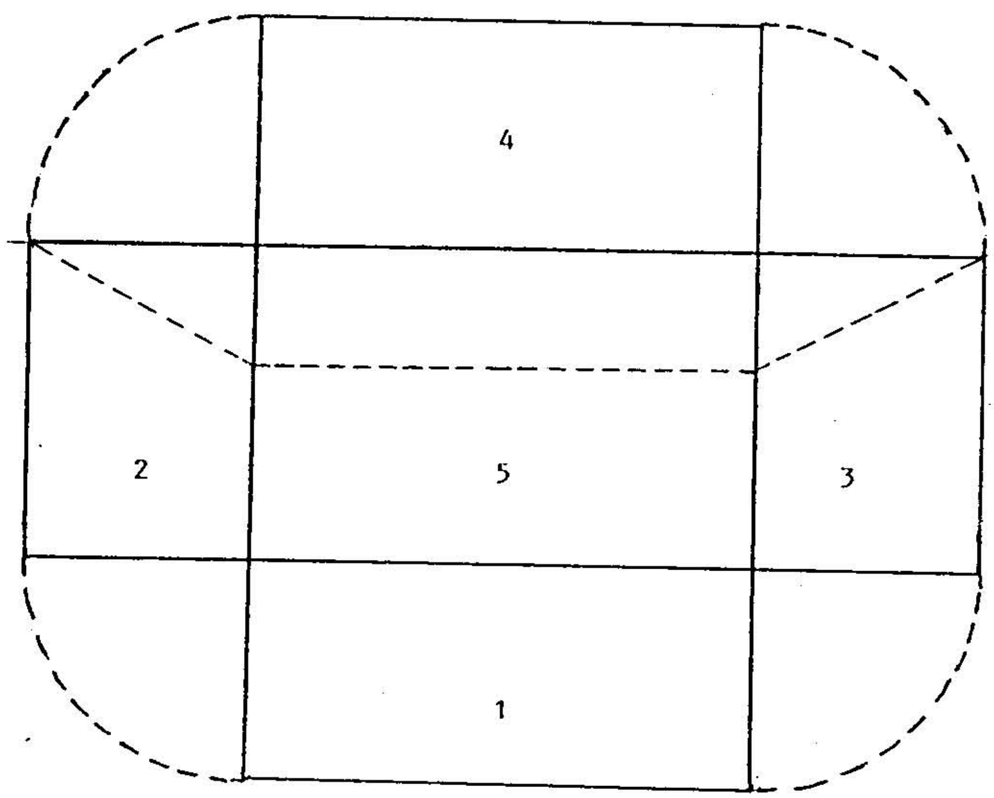
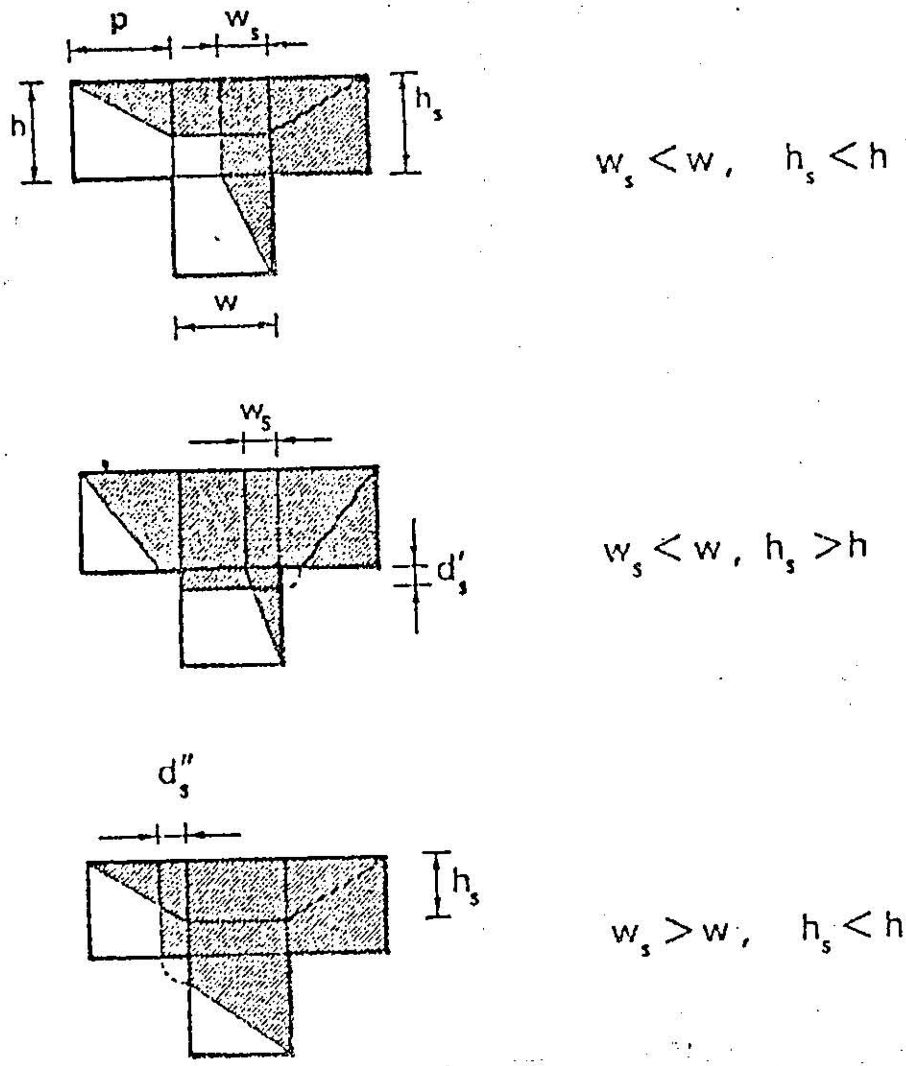
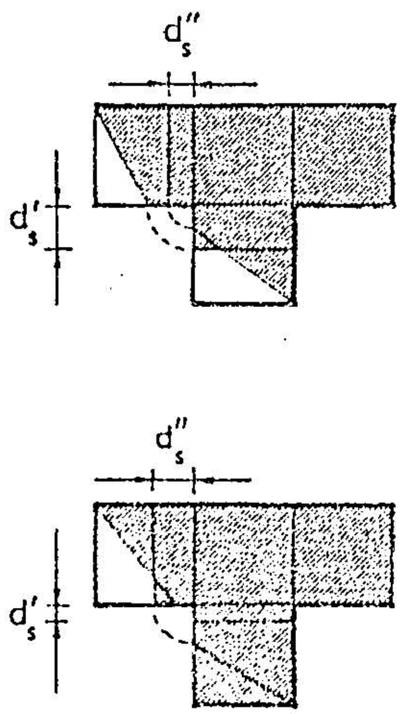


Fig (2.9) Shade geometry of receiver noon- open view



Fig(2.10) Possible Shade configurations
of direct beam radiation



$w_s > w, \quad h_s > h, \quad d_s' > d_s''$

$w_s > w, \quad h_s > h, \quad d_s' < d_s''$

b)

case1: $w_s < w$, $h_s<h$.

$$f_1 = 1- (h_s/2h). \quad (2.56)$$

$$f_2 = 1- (w_s/2w). \quad (2.57)$$

Case2: $w_s<w$, $h_s>h$.

$$f_1 = (1-d_s'/p)/2. \quad (2.58)$$

$$f_2 = 1-d_s'/p - (1-d_s'/p)^2\, w/2w_s \quad (2.59)$$

with

$$d_s' = p \tan(\Omega)-h/\tan(\Omega) \quad (2.60)$$

$$\text{and } \Omega = \tan^{-1}[\tan\alpha / \cos(\gamma_s-\gamma)] \quad (2.61)$$

case3: $w_s>w$, $h_s<h$.

$$f_1 = 1-d_s''/p - (1-d_s''/p)^2\, h_s/2h \quad (2.62)$$

$$f_2 = (1-d_s''/p)/2 \quad (2.63)$$

with : $d_s'' = [p \tan(\gamma_s-\gamma)-w]/\tan(\gamma_s-\gamma)$ ......(2.64)

case4: $w_s>w$, $h_s>h$ and $d_s'>d_s''$.

$$f_1 = (1-d_s'/p)/2 \quad (2.65)$$

$$f_2 = (1-d_s'/p)[1-(p-d_s')/2(p-d_s'')] \quad (2.66)$$

case5: $w_s>w$, $h_s>h$ and $d_s' < d_s''$

$$f_1 = (1-d_s''/p)[1-(p-d_s'')/2(p-d_s')] \quad (2.67)$$

$$f_2 = (1-d_s''/p)/2 \quad (2.68)$$

Where $\gamma_S<\gamma$. The above expression for f_1 remain unchanged, expression given for f_2 hold for f_3 and f_2 is zero.

The Incidence angles on the eggcrate sides are given by[8]:

$$\text{Cos}\ \phi_2 = \cos\alpha\ \cos(\gamma s - \gamma + 90) \quad (2.69)$$

$$\text{Cos}\ \phi_1 = \sin\alpha \quad (2.70)$$

$$\text{Cos}\ \phi_3 = \cos\alpha\ \cos(\gamma_S - \gamma + 90) \quad (2.71)$$

Eggcrate sides to sky and ground view factors are estimated by the following relationship, which holds for two rectangles with common edge and included angle of 90° from Ref[8].

$$F = (1/\pi L)\left[L \tan^{-1}(1/L) + N \tan^{-1}(1/N) - (N^2 L^{2)})^{1/2} x \right.$$
$$\left. \tan^{-1}(N^2+L^2)^{-1/2}\right] +$$
$$(1/4\pi L) Ln\left\{\left[(1+L^2)(1+N^2)/(1+N^2+L^2)\right] x\right.$$
$$\left[L^2(1+L^2+N^2)/(1+L^2)(L^2+N^2)\right]L^2$$
$$\left. x\left[N^2(1+N^2+L^2)/(1+N^2)(L^2+N^{2)})\right]N^2\right\} \quad (2.72)$$

Taking into account the symmetry the following relation holds:

$$F_{2,s} = F_{2,g} = F_{3,s} = F_{3,g} = F/2 \quad (2.73)$$

with

$$L = P/h \qquad N = w/h$$

and

$$F_{1,s} = F_{4,g} = F$$

with

$L = h/w \qquad N = p/w$

The radiant flux circulating in the enclosure after one reflection is given as:

$$\Phi^{(o)} = \Phi_b^{(o)} + \Phi_d^{(o)} + \Phi_g^{(o)} \quad \text{.......................................} \quad (2.74)$$

And since it is assumed to be diffuse after n+1 reflections it reducces to

$$\Phi^{(n)} = \rho_m^{(n)} \Phi^{(o)} \quad \text{..} (2.75)$$

Where ρ_m is the average reflectivity of the inclosure

$$\rho_m = \frac{\sum_{i=1}^{4} A_i \rho_i}{2A + \sum_{i=1}^{4} A_i} \quad \text{..} (2.76)$$

By summation over an infintie number of terms the total radiant flux circulating inside the enclosure is obtained as:

$$\Phi = \sum_{k=0}^{\infty} \Phi^{(k)} = \frac{\rho_m}{1-\rho_m} \Phi^{(0)} \quad \text{...} (2.77)$$

reflected radiation on the receiver is given by:

$$I_r = \Phi/A \quad \text{..} (2.78)$$

3- The average daily radiation on the vertical window ($\overline{H}_t$) for given direction without overhang for each month was calculated.

4- The average daily radiation on vertical window with overhang with given overhang ratio for the same direction was calculated for each month ($\overline{H}^*$).

5- The average summer daily radiation for shaded and unshaded window were calculated and the summer months were assumed to be months from May to October so that HS_u=average summer daily radiation for unshaded window so that:-

$$HS_u = \sum_{i=5}^{10} \overline{H}_t(i)$$

and for shaded window HSs:

$$HS_s = \sum_{i=5}^{10} \overline{H}^*(i)$$

6- The average winter daily radiation for shaded and unshsded window was calculated, and the winter months from November to April so that :-

HW_u =average winter daily radiation for unshaded window so:-

$$HW_u = \sum_{i=5}^{10} \overline{H}_t(i)$$

and for shaded window HWs

$$HW_s = \sum_{i=11}^{4} \overline{H}^*(i)$$

7- The summer performance is some kind of efficiency for the shading device which is defined as the ratio of the amount of energy obscured by the shading device to the energy reaching the window using the device or:-

$$S.P = \frac{HS_u - HS_s}{HS_u} \times 100\%$$

The winter performance, is defined some what differently, which is the ratio of energy reaching the window when the device is used to that with no device, or

$$W.P = \frac{HW_s}{HW_u} \times 100\%$$

These performances were calculated for different overhang ratios $\left(Z = \frac{X}{Y}\right)$ and for different surface azimuth angles (window orientation).

8- The above stepes were repeated for overhang ratios from Z=0.1 to Z=1.2 and for different direction from South to North, or from (γ=0.0 to $\gamma=\pm180$)

9- The summer perfomance and winter performance were plotted against overhang ratio on the same curve, for several orientations and for the case were the overhang extends directely from the top of the window.

10- The results are shown in Fig(3.1) to Fig(3.19) and tables are in Appendix B; Tabel(B.1) to Table(B.24)

11- For the general case of overhang where the overhang is seperated by a section of vertical wall from the window, the results are shown in Fig(3.20) to Fig(3.29)

The same caculation were performed for the eggcrate shading device and the above steps were repeated for this device, Since the eggcrate shading device depends on the shape of the window, therefore the possible shapes of windows were taken as:-

a- Square windows geometries,

$$h = 1.0,\ W = 1.0$$

b- Vertical windows geometries

$$h = 4.0,\ W = 0.25$$

c- Horizontal windows geometries

$$h = 0.25,\ W = 4.0$$

The results are shown in the following Figures:

Fig(3.30-3.48) for square windows

Fig(3.49-3.67) for vertical windows and

Fig(3.68-3.86) for horizontal windows

Summer and Winter

Performance Curves for

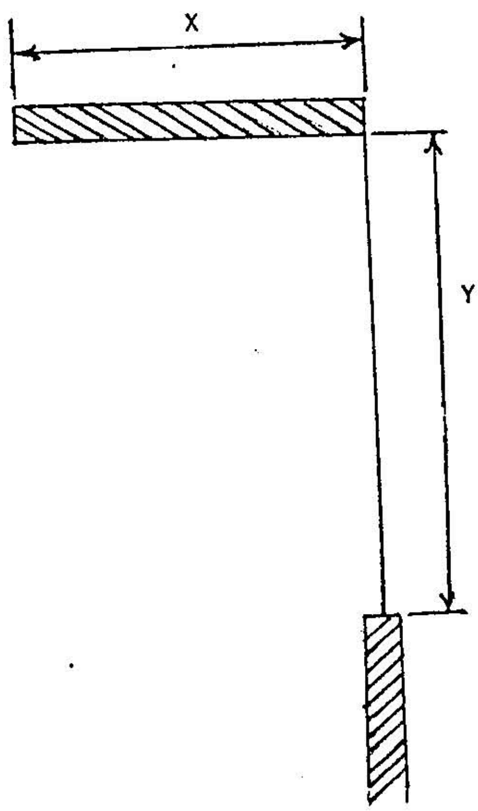
Overhang without

Separation from the

Top of Window

Fig(3.1) - Fig(3.19)

Z=X/Y



$\gamma = 0.0$

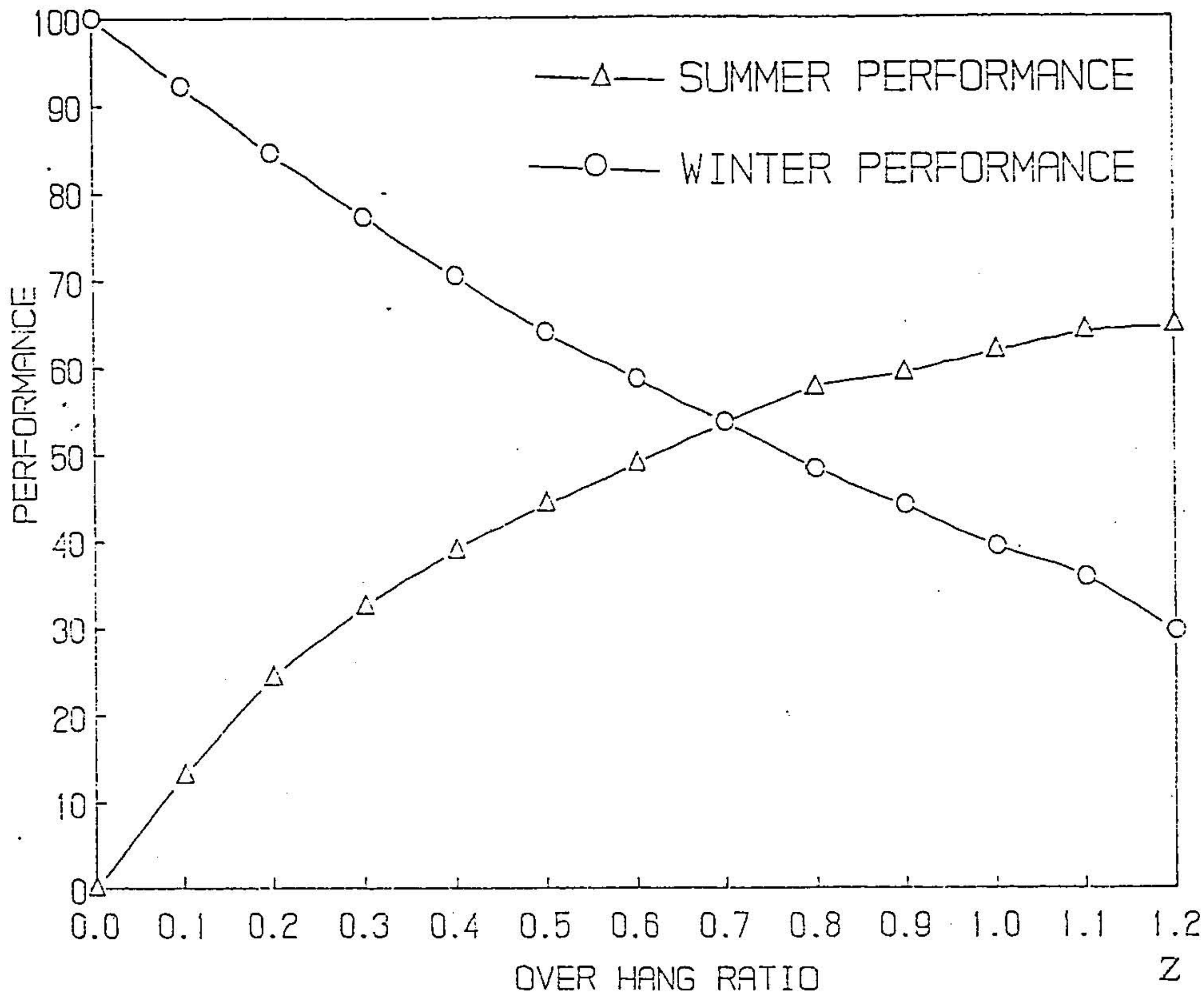


Fig (3.1)

$\gamma = 10.0$

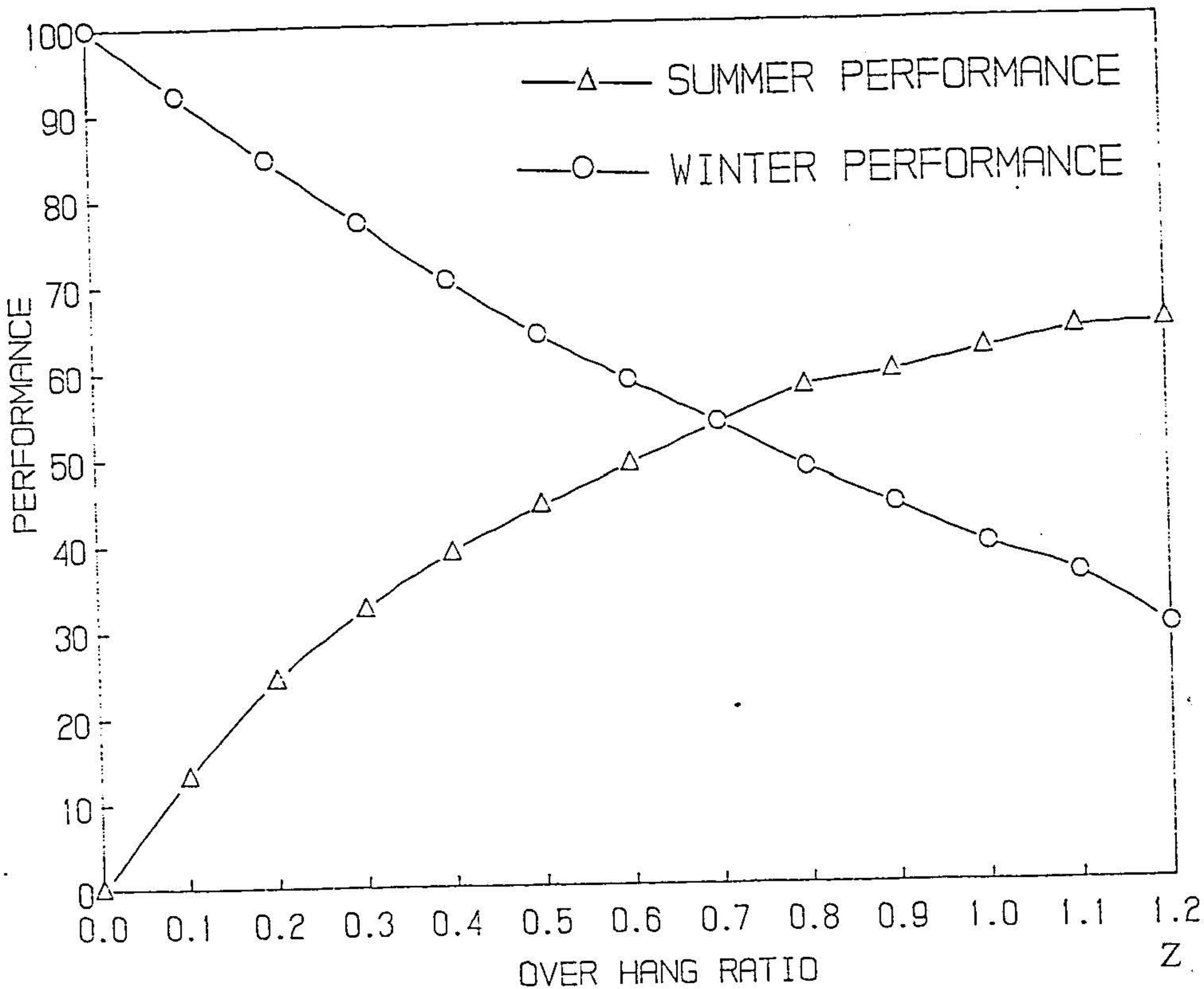


Fig (3.2)

$\gamma = 20.0$

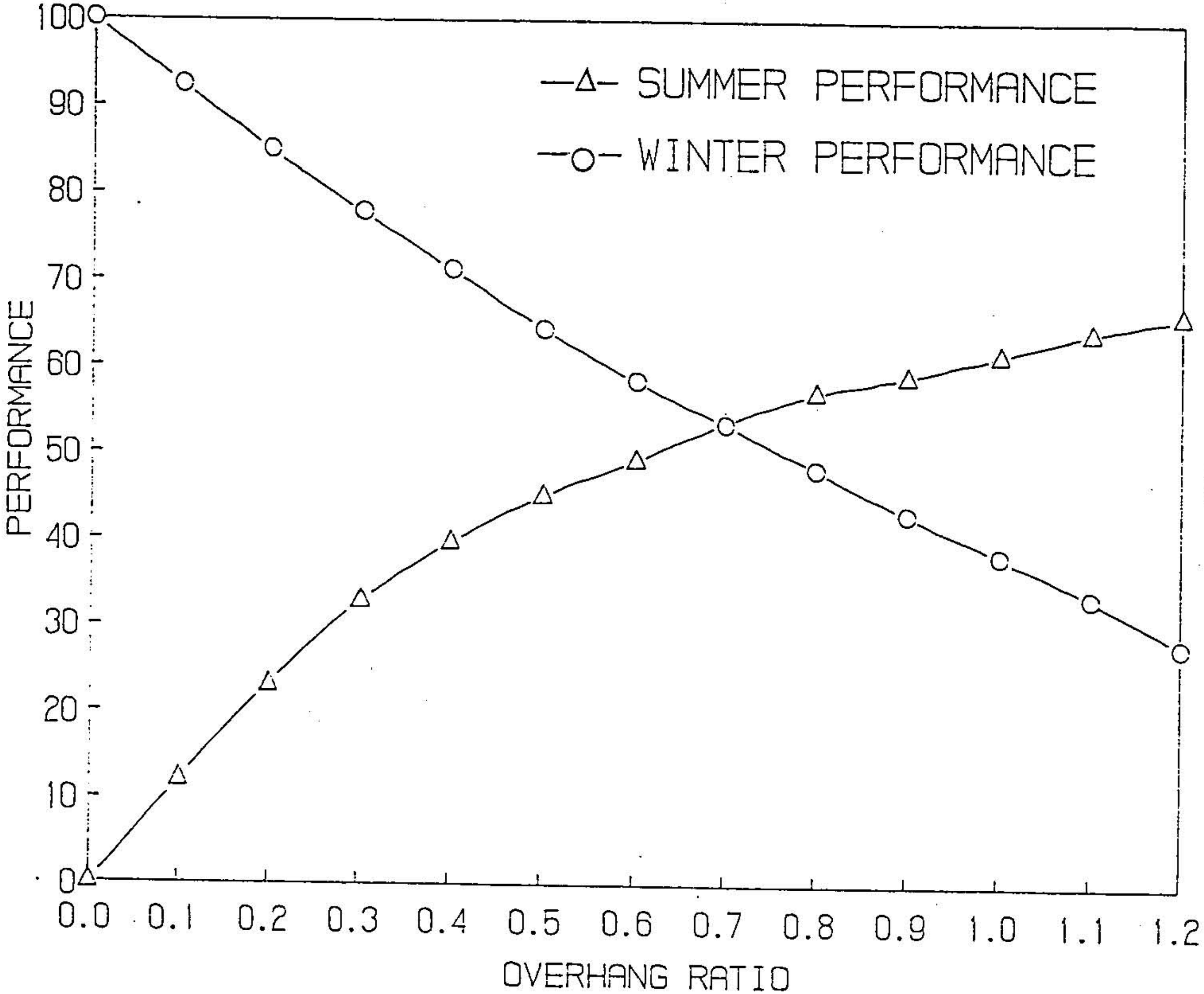


Fig (3.3)

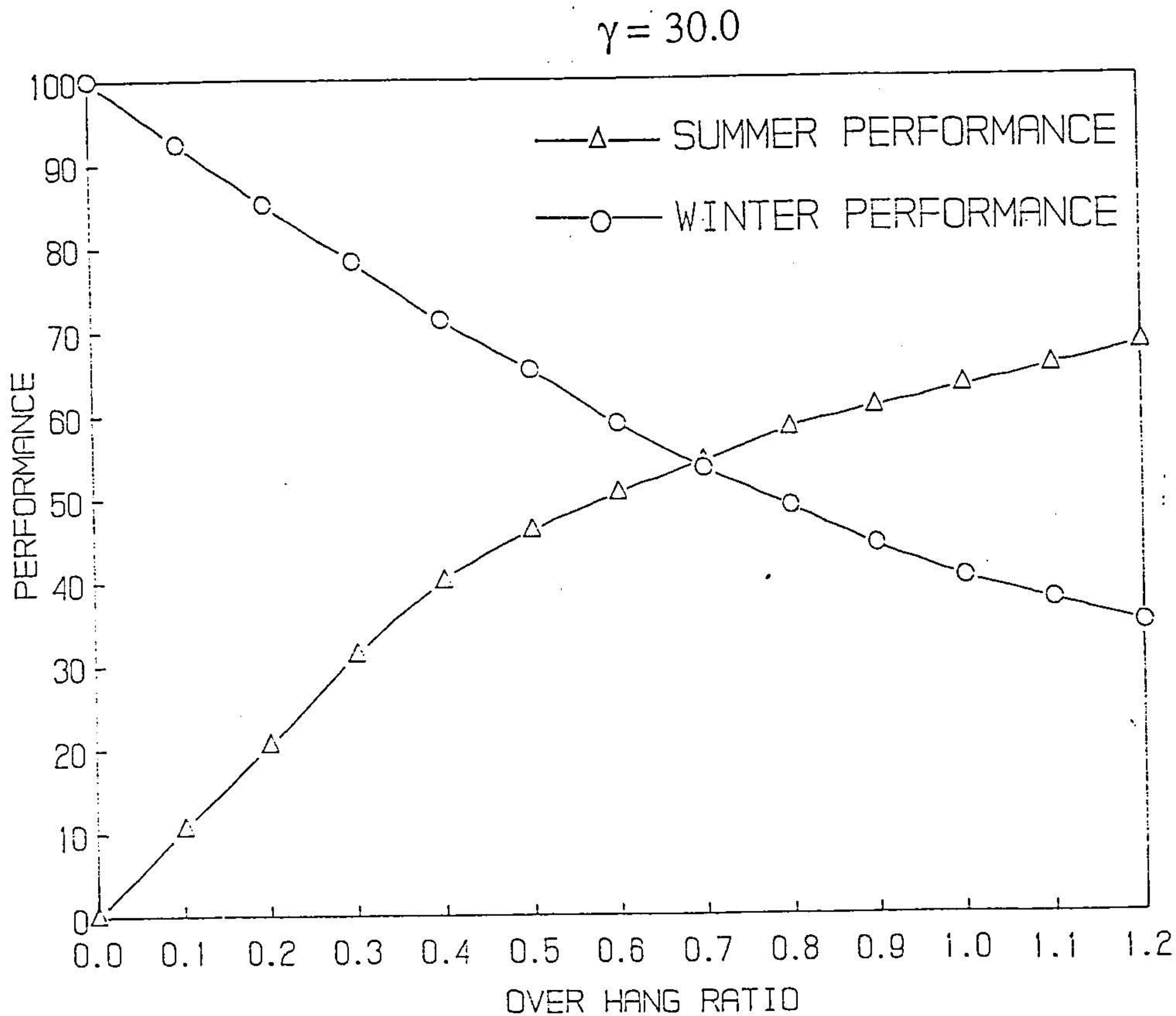

γ = 30.0
SUMMER PERFORMANCE
WINTER PERFORMANCE
PERFORMANCE
100
90
80
70
60
50
40
30
20
10
0
0.0
0.1
0.2
0.3
0.4
0.5
0.6
0.7
0.8
0.9
1.0
1.1
1.2
OVER HANG RATIO

Fig (3.4)

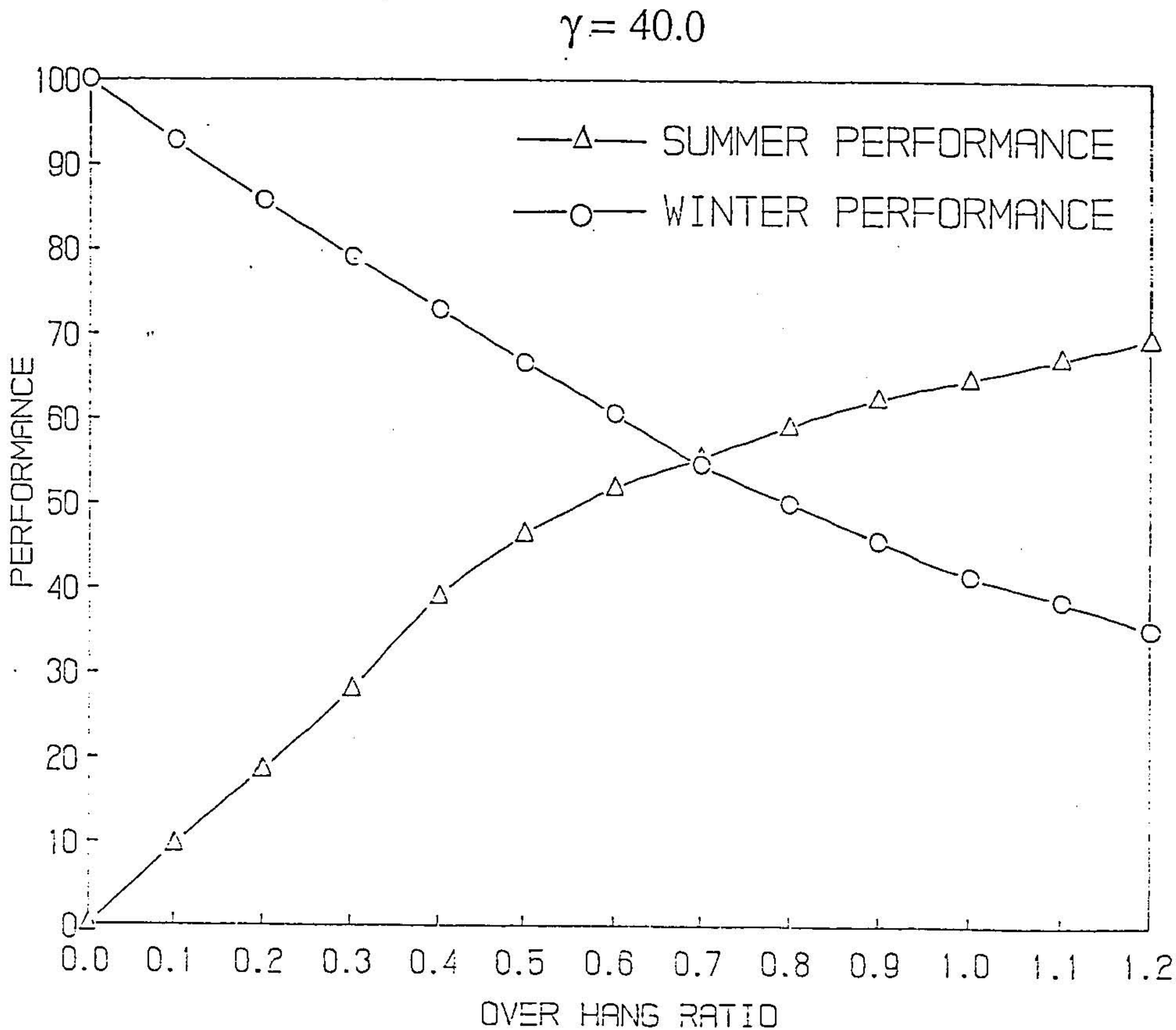

γ = 40.0
SUMMER PERFORMANCE
WINTER PERFORMANCE
PERFORMANCE
100
90
80
70
60
50
40
30
20
10
0
0.0
0.1
0.2
0.3
0.4
0.5
0.6
0.7
0.8
0.9
1.0
1.1
1.2
OVER HANG RATIO

Fig (3.5)

$\dot{\gamma} = 50.0$

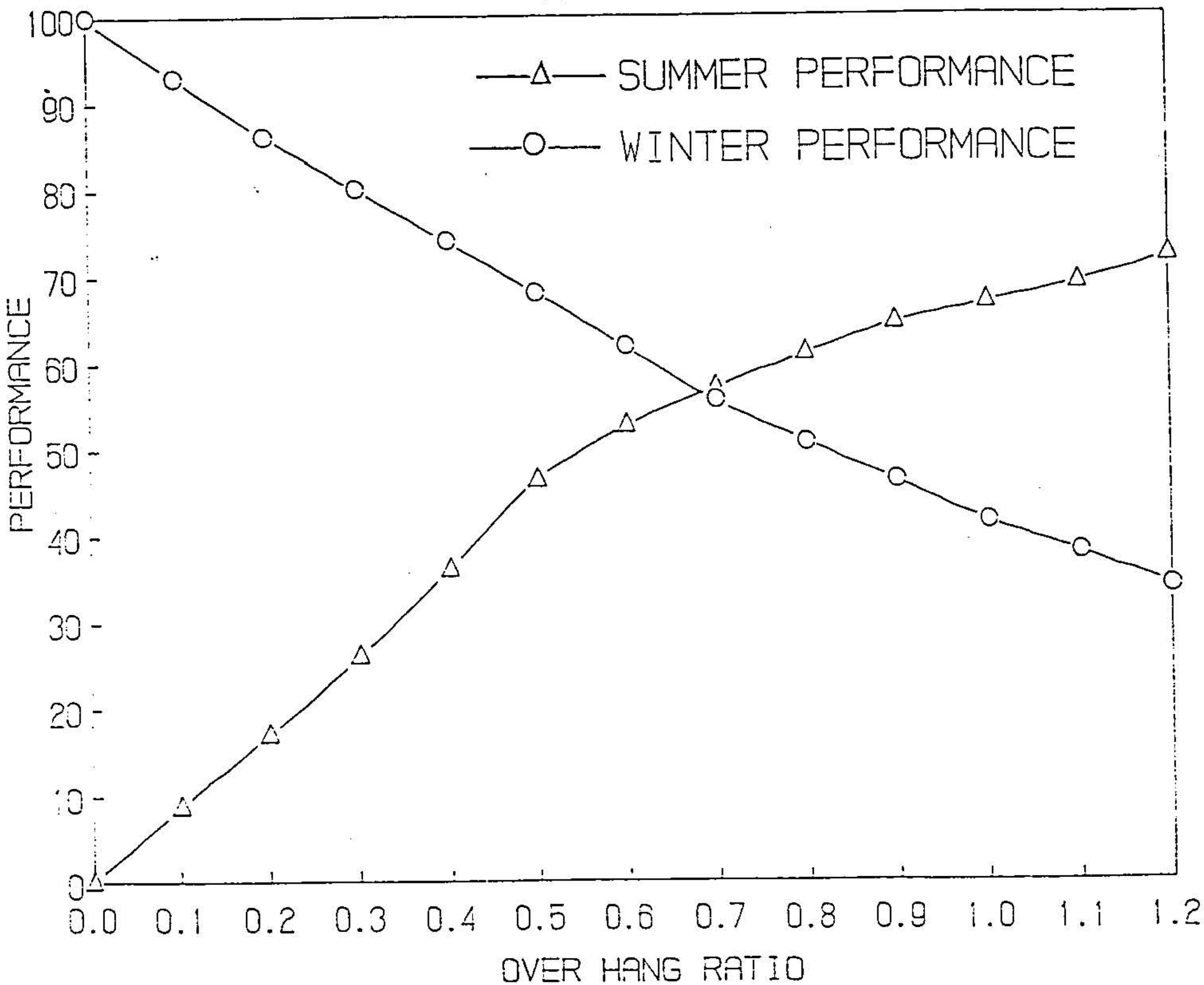


Fig (3.6)

$\gamma = 60.0$

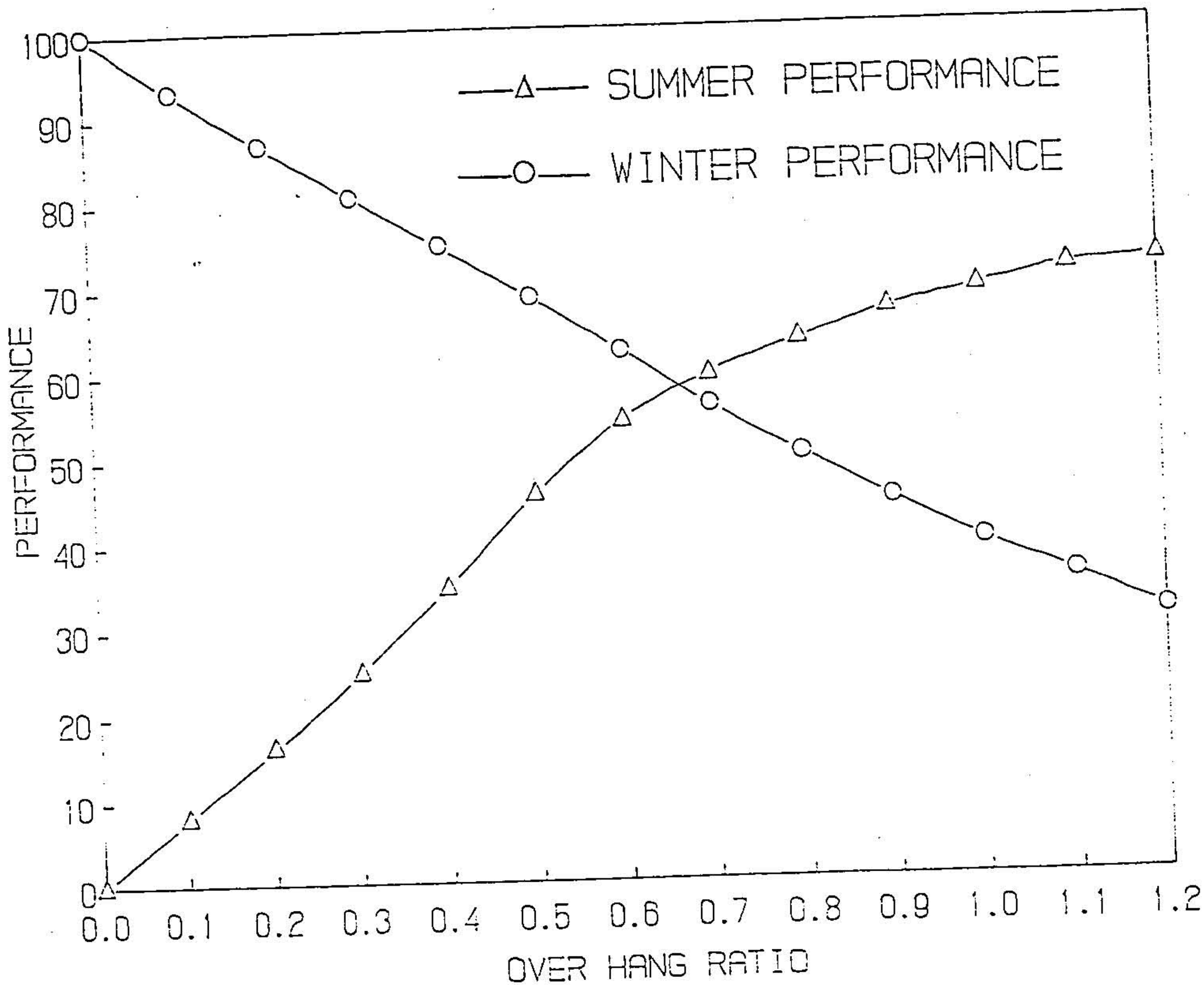


Fig (3.7)

$\gamma = 70.0$

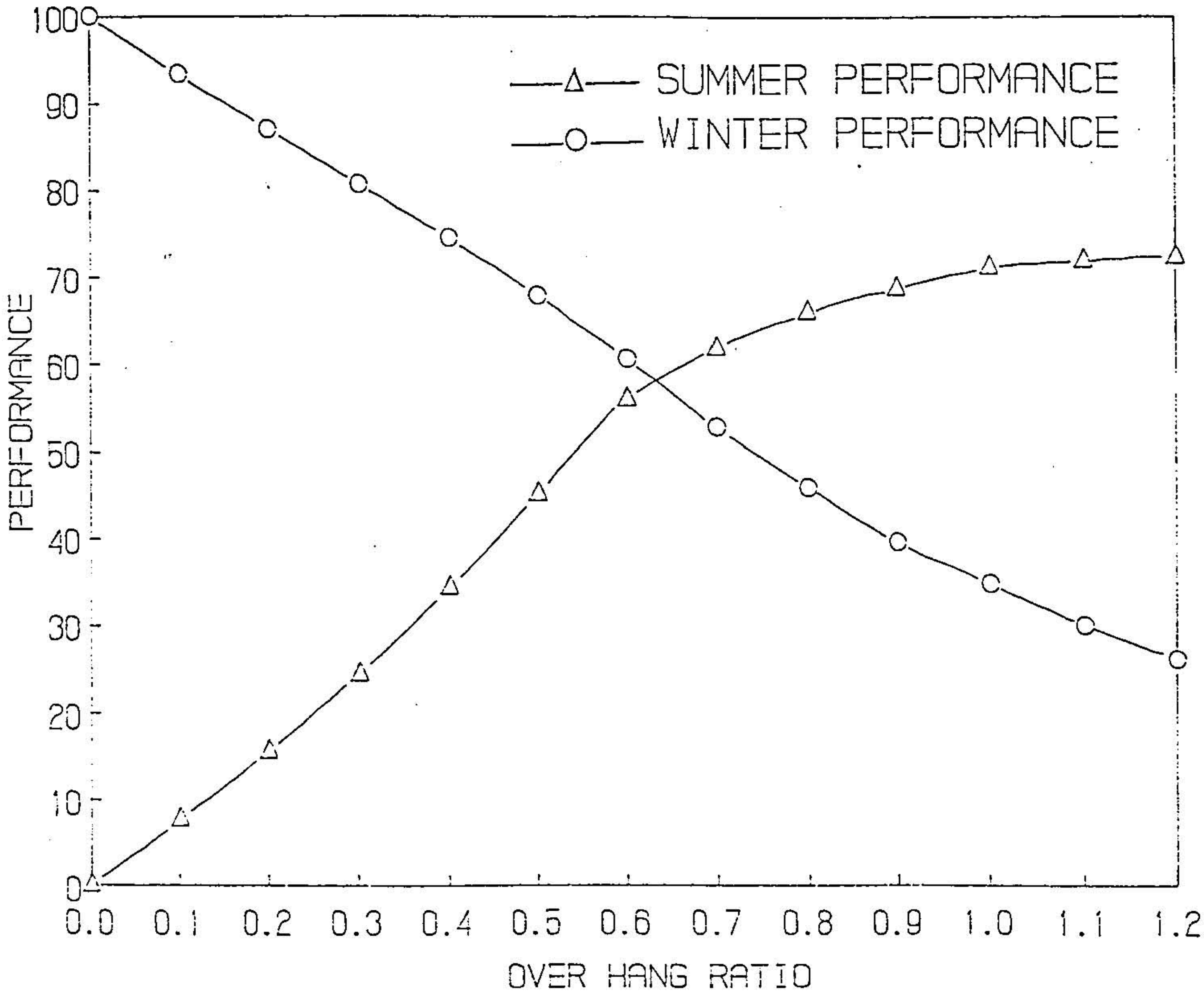


Fig (3.8)

$\gamma = 80.0$

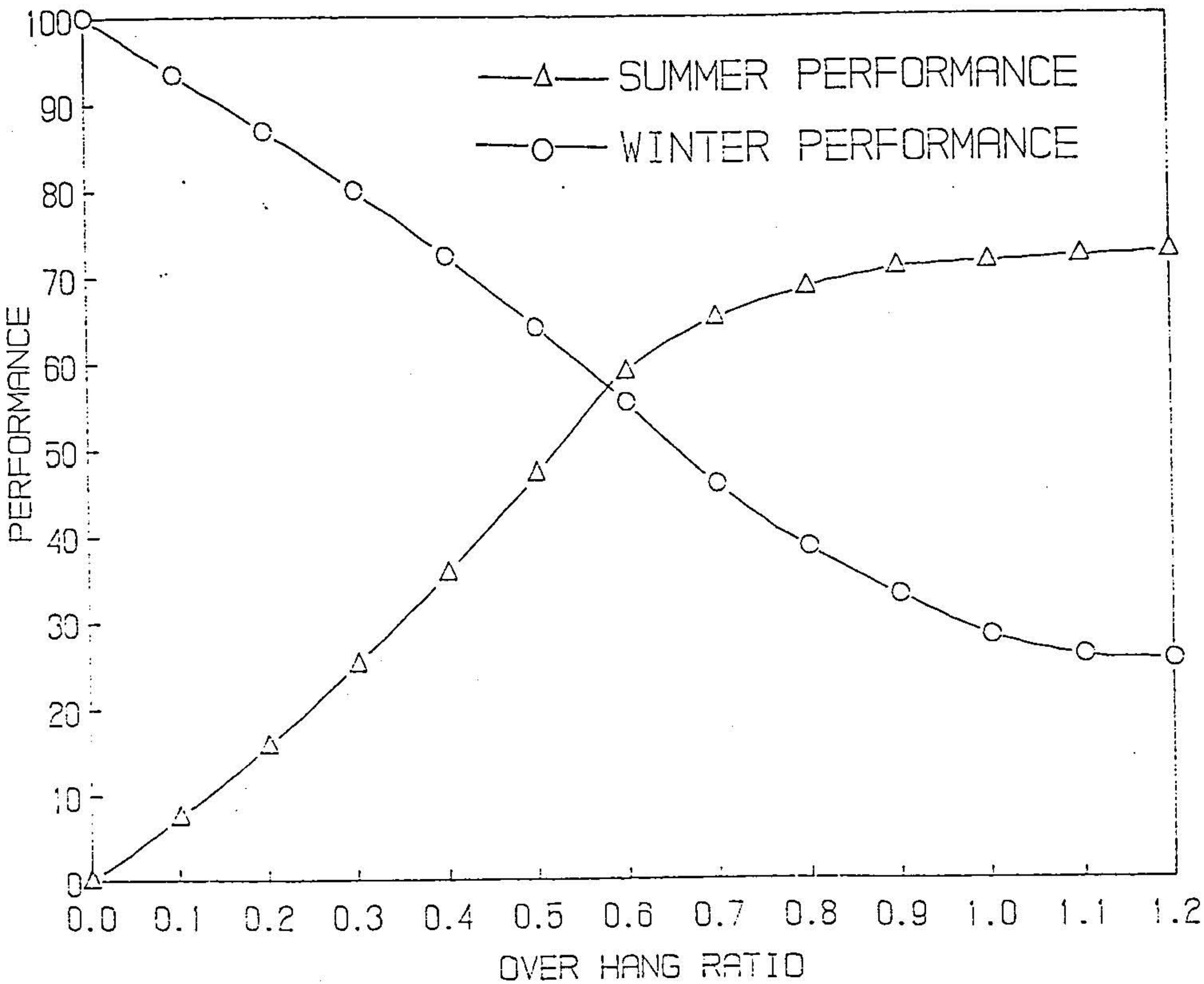


Fig (3.9)

$\gamma = 90.0$

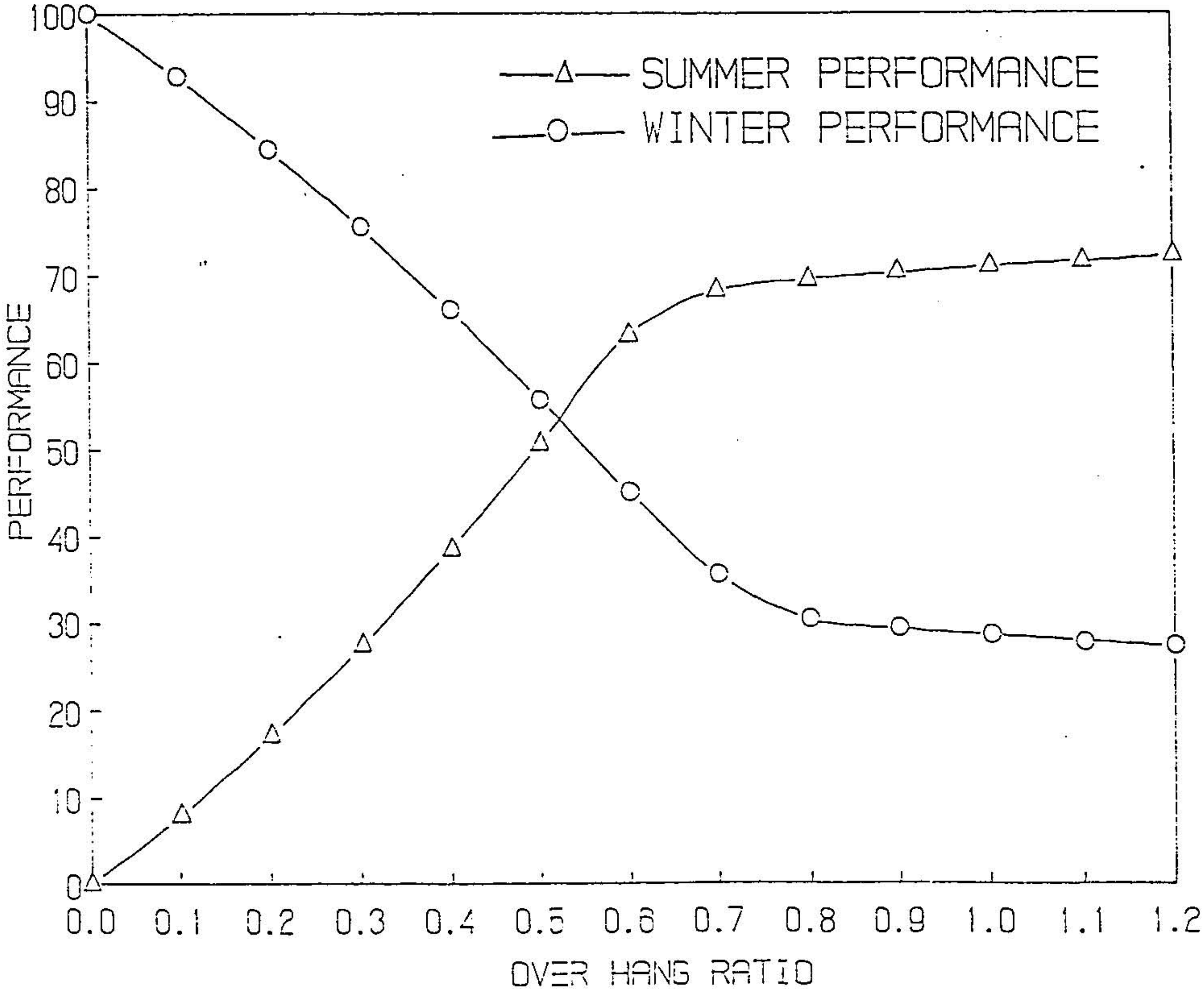


Fig (3.10)

$\gamma = 100.0$

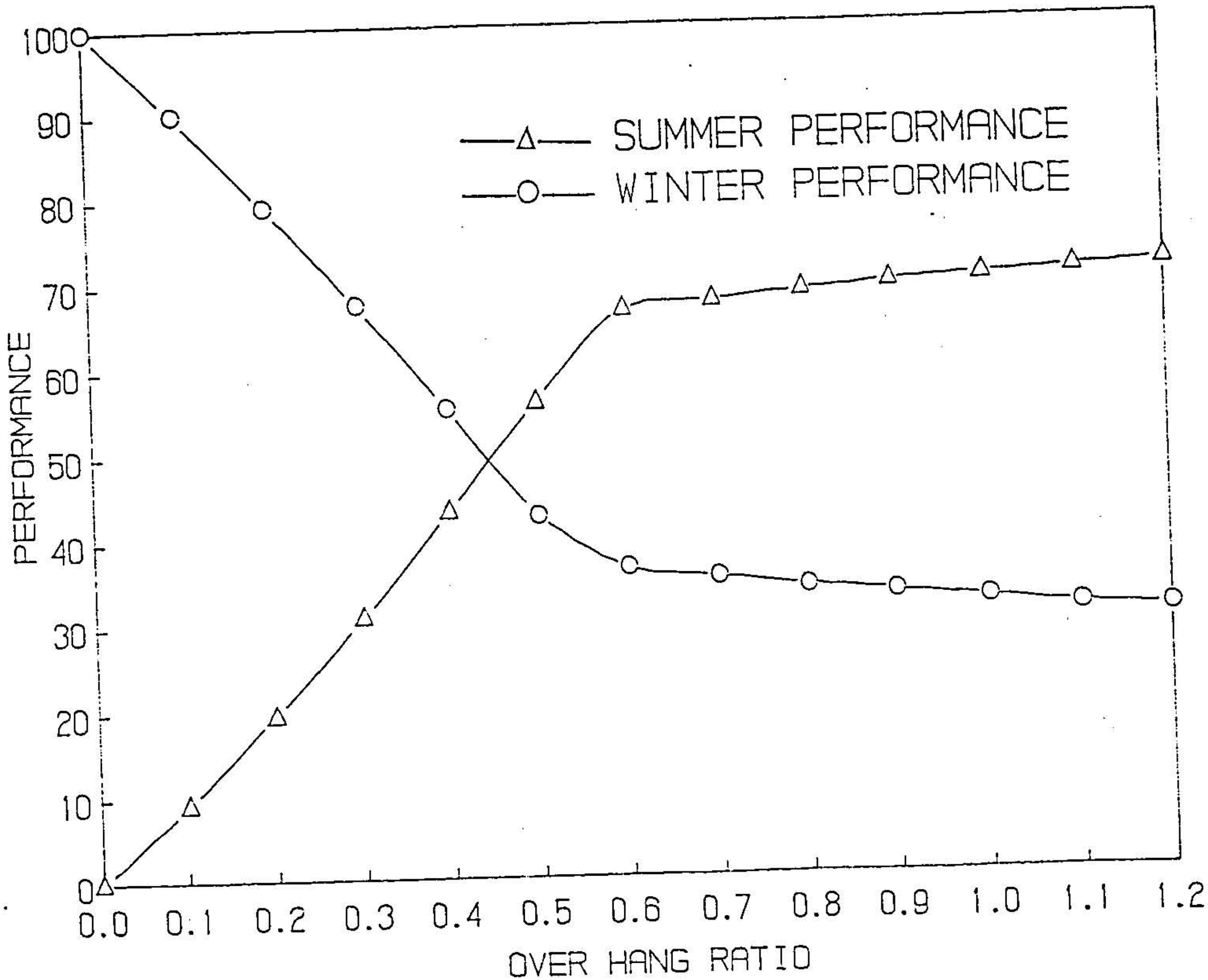


Fig (3.11)

$\gamma = 110.0$

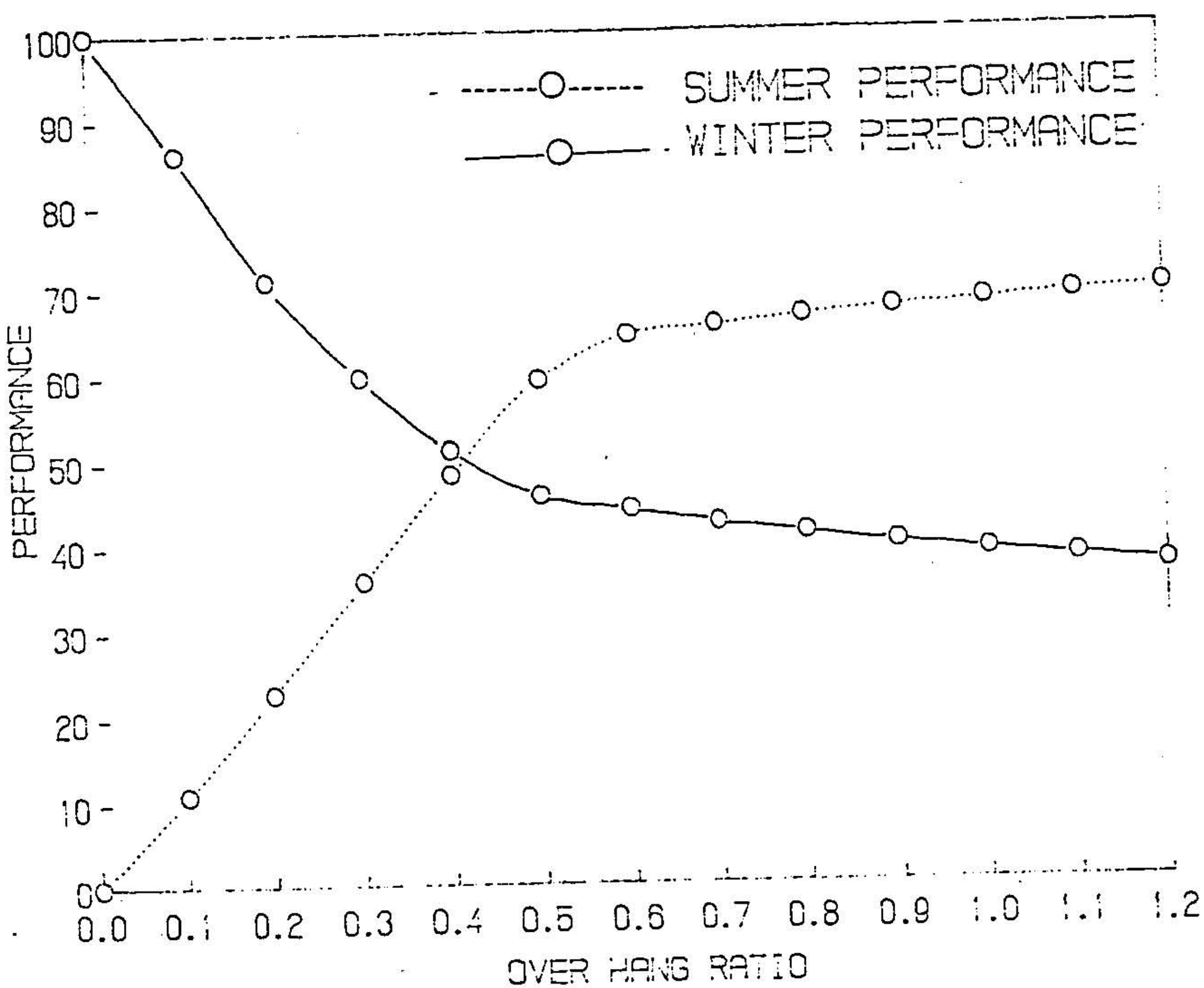


Fig (3.12).

$\gamma = 120.0$

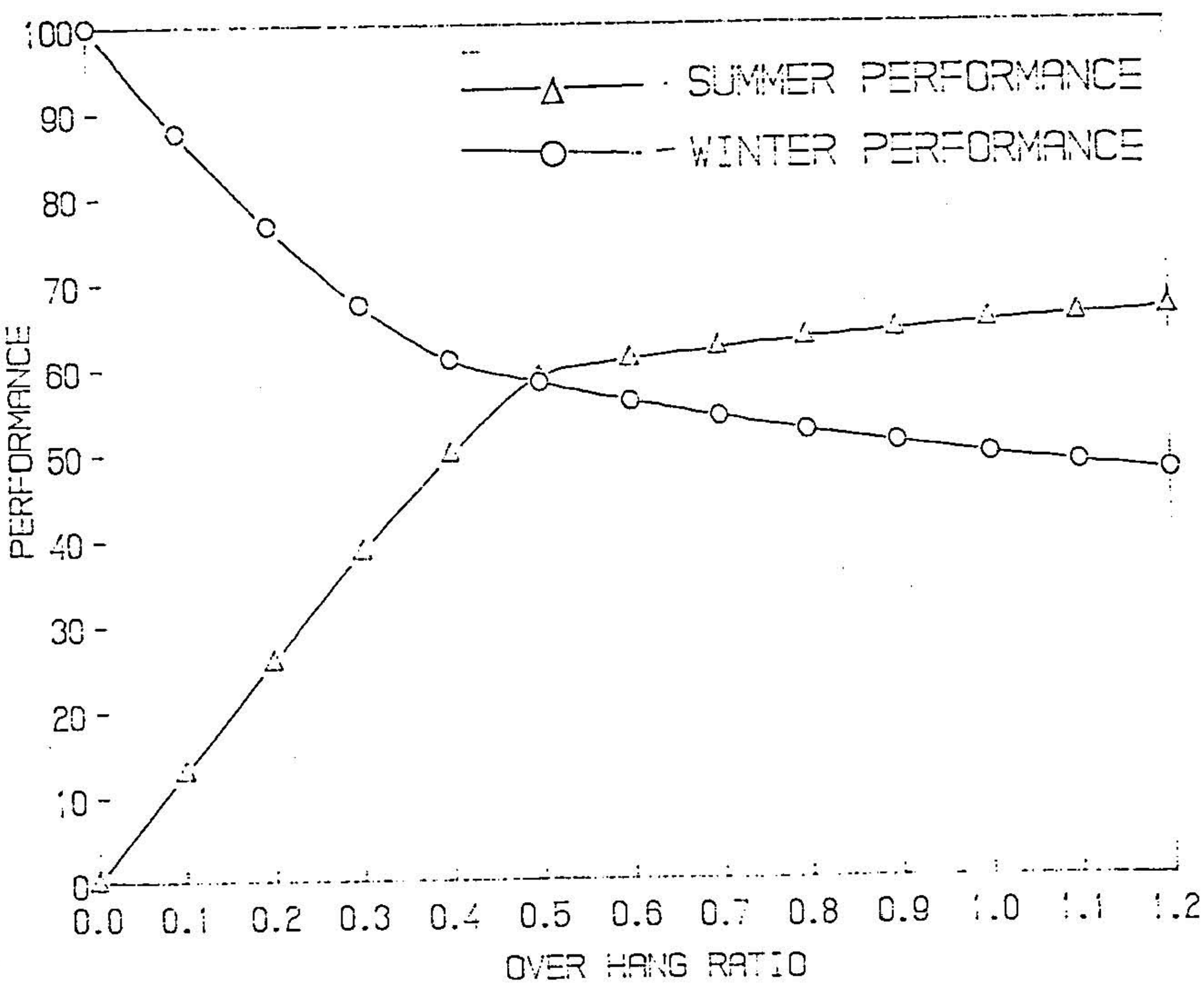


Fig (3.13)

$\gamma = 130.0$

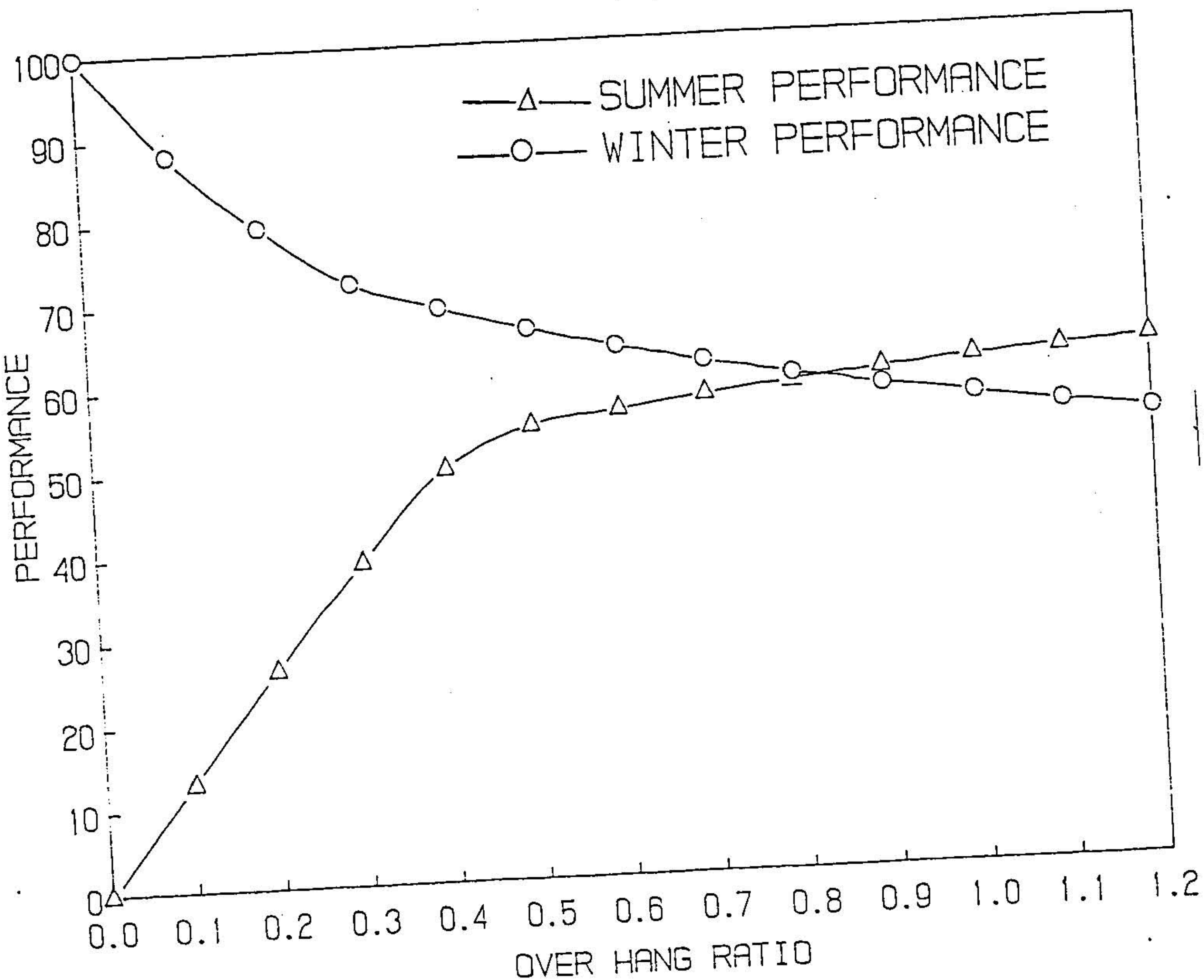


Fig (3.14)

$\gamma = 140.0$

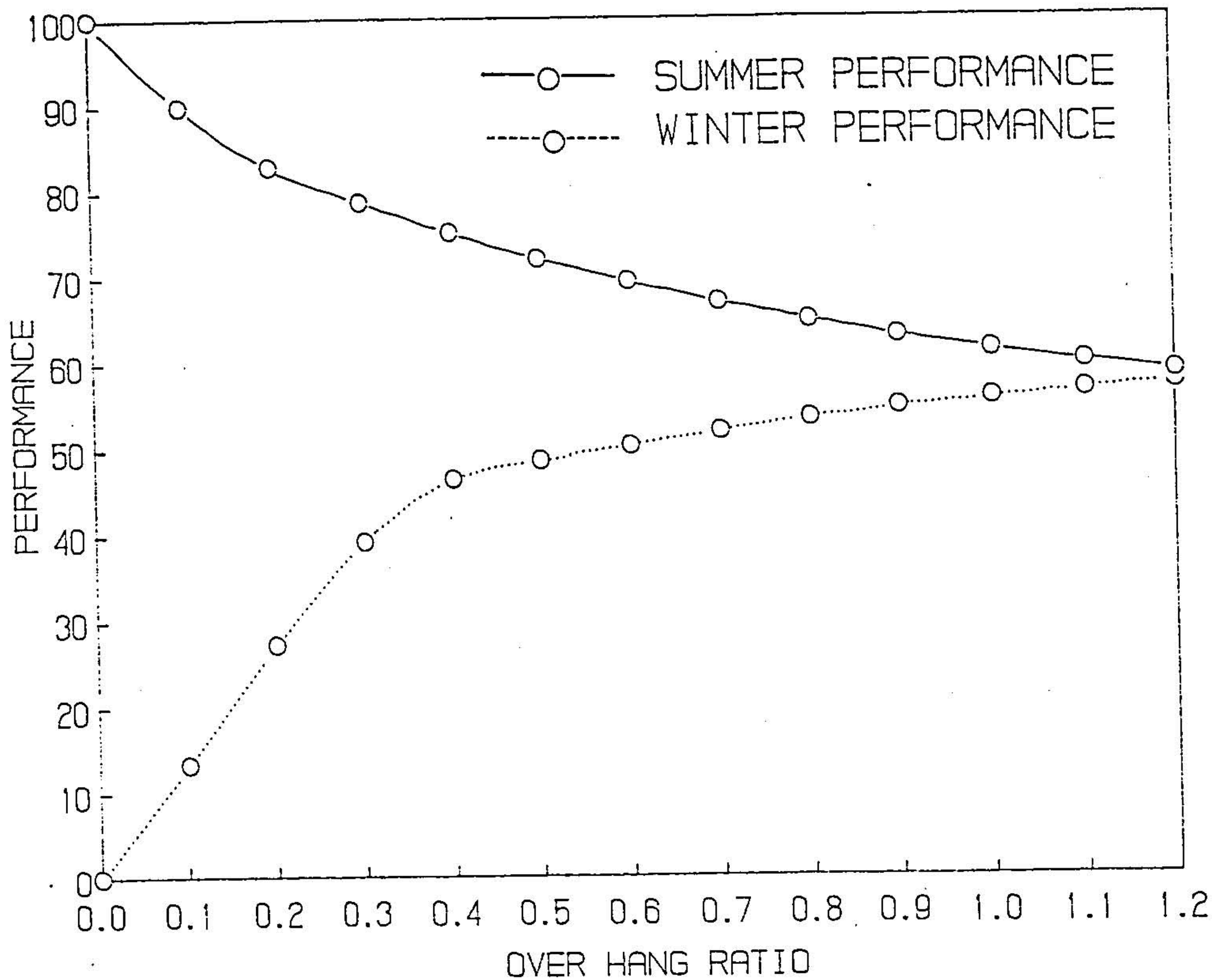


Fig (3.15)

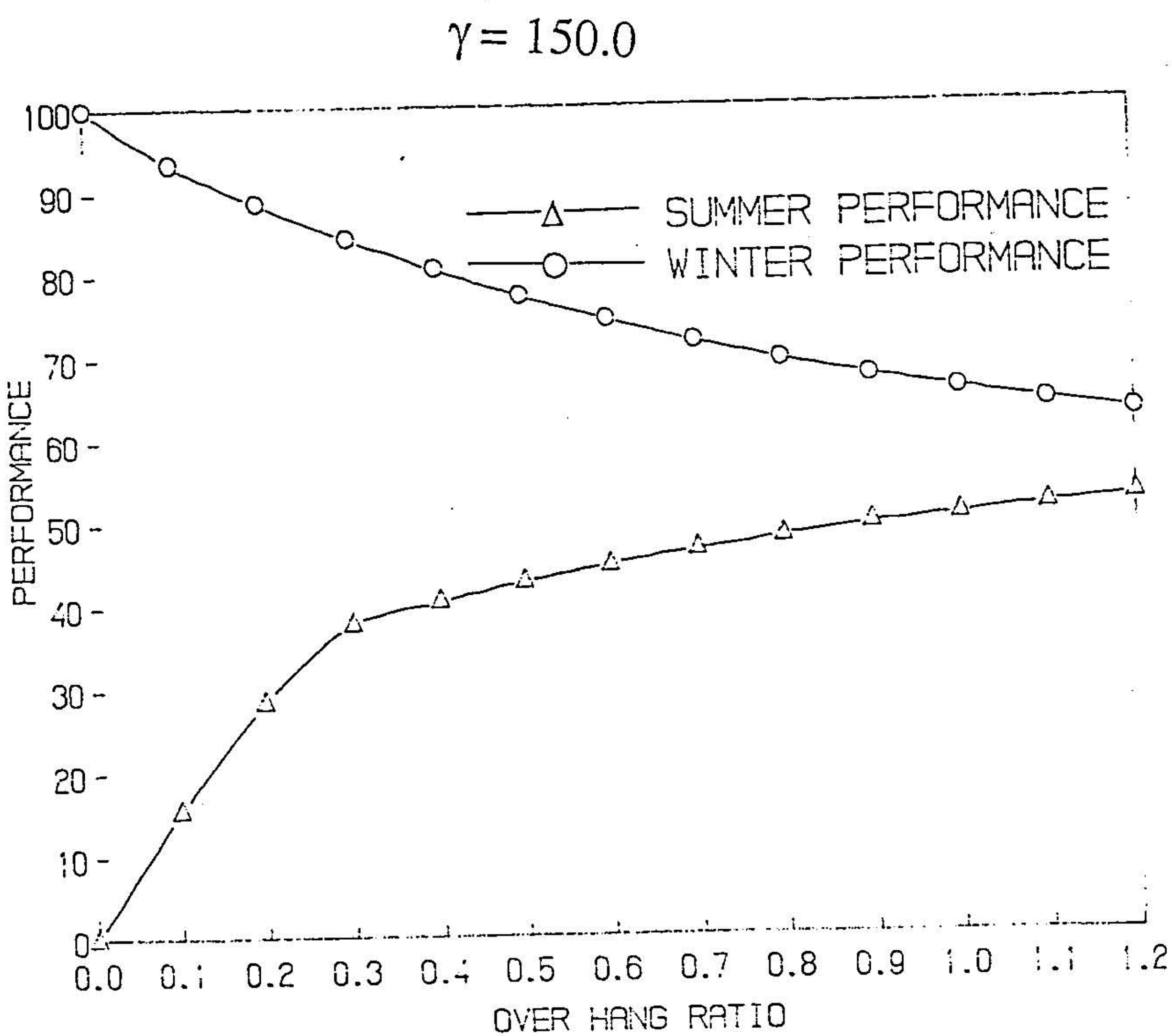

γ = 150.0
SUMMER PERFORMANCE
WINTER PERFORMANCE
PERFORMANCE
OVER HANG RATIO
100
90
80
70
60
50
40
30
20
10
0
0.0
0.1
0.2
0.3
0.4
0.5
0.6
0.7
0.8
0.9
1.0
1.1
1.2

Fig (3.15)

58

$\gamma = 160.0$

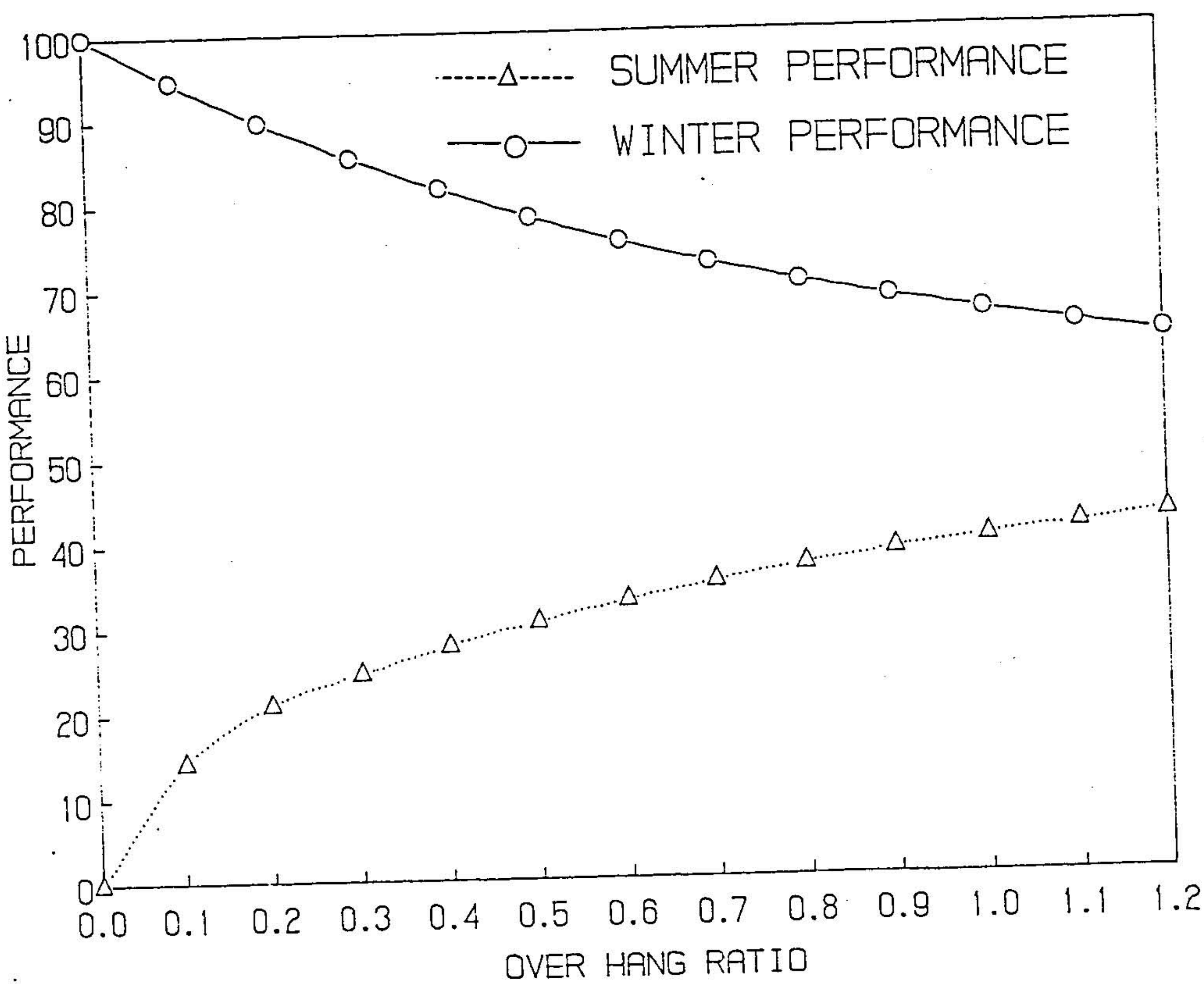


Fig (3.17)

$\gamma = 170.0$

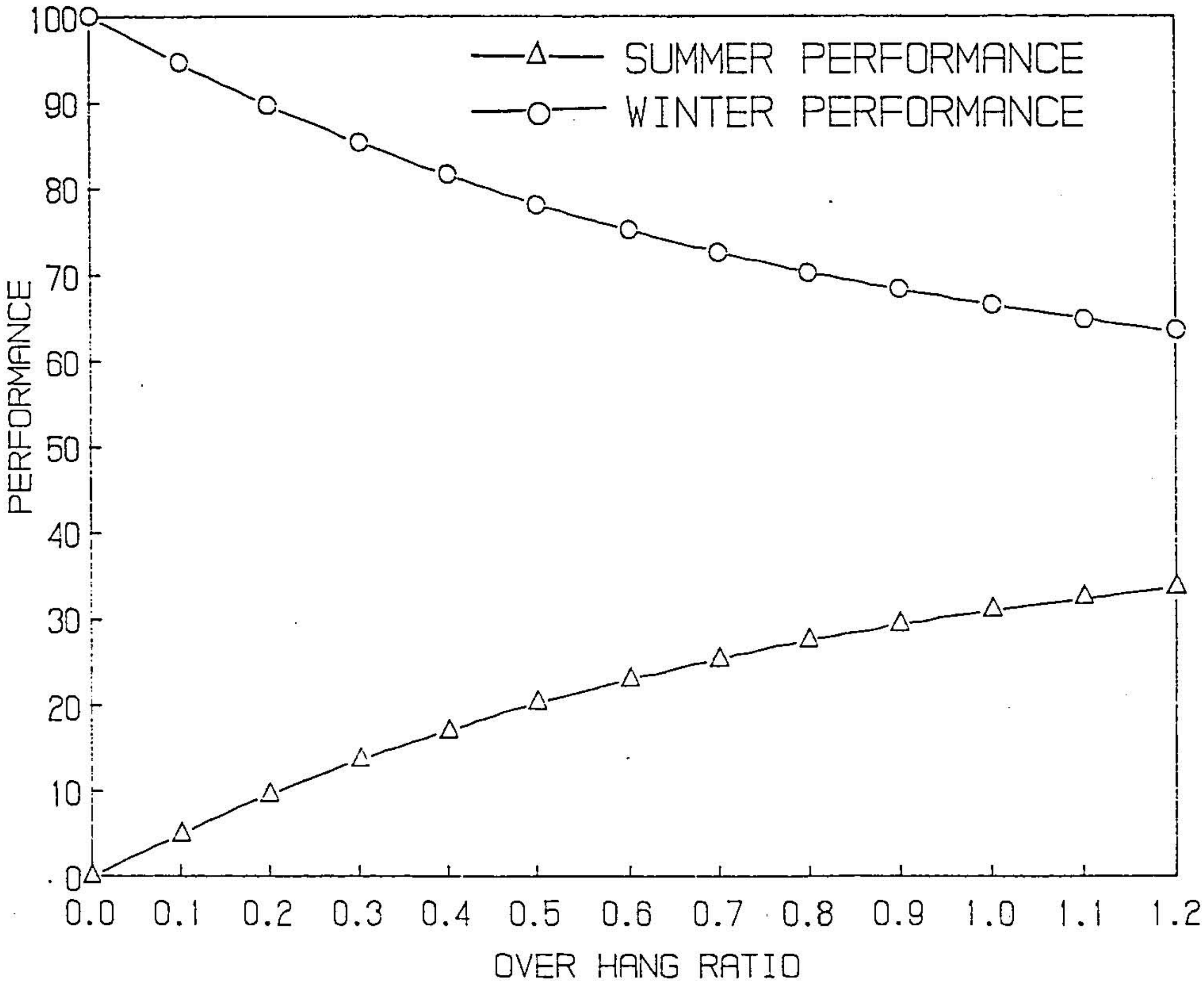


Fig (3.18)

$\gamma = 180.0$

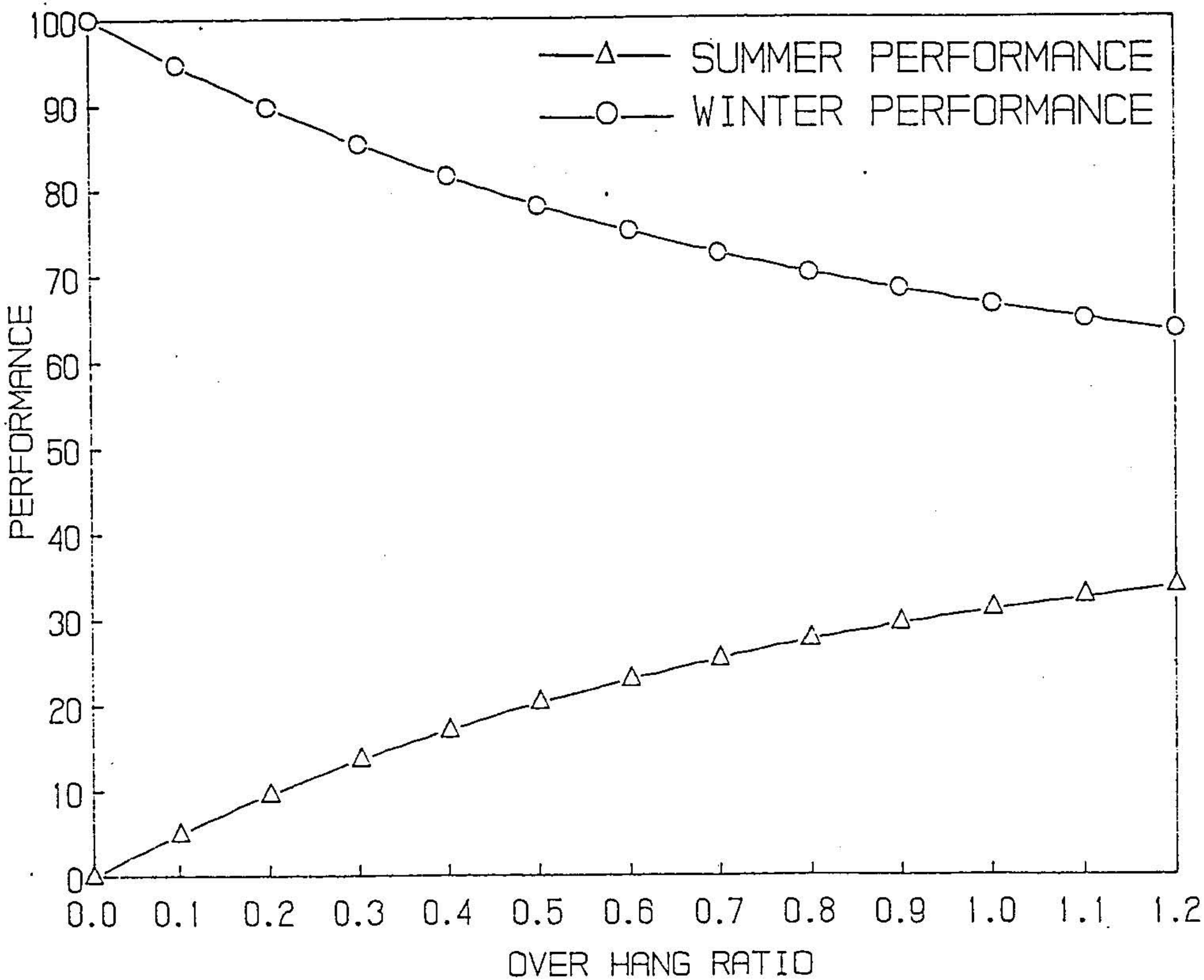


Fig (3.19)

Summer and winter performance curves for overhang in General Gase Fig (3.21) - Fig (3.29)

$$Z_1 = \frac{X}{Y_1}$$

$$Z_2 = \frac{X}{Y_2}$$

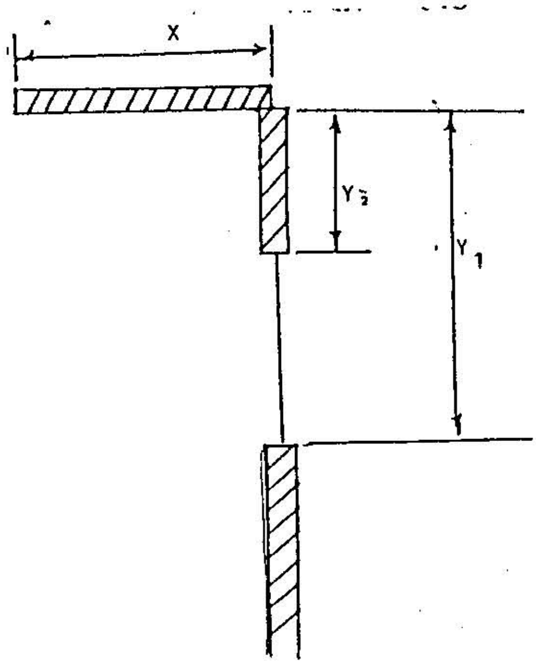
-----O----- summer performance for $Z_1 = 0.2$
-----Δ----- summer performance for $Z_1 = 0.4$
-----□----- summer performance for $Z_1 = 0.6$
-----✱----- summer performance for $Z_1 = 0.8$

——O—— winter performance for $Z_1 = 0.2$

——Δ—— winter performance for $Z_1 = 0.4$

——□—— winter performance for $Z_1 = 0.6$

——✱—— winter performance for $Z_1 = 0.8$



$\gamma = 0.0$

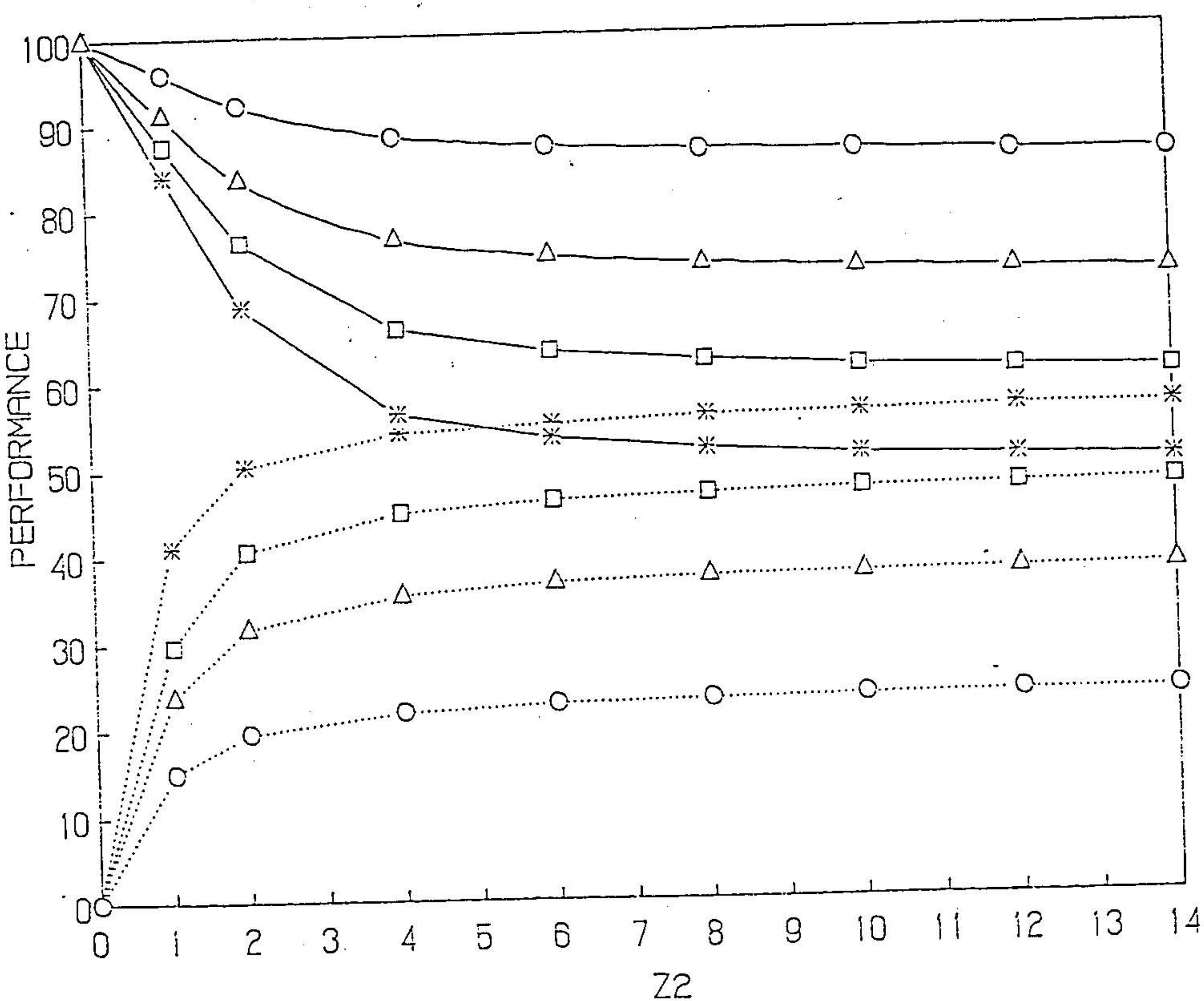


Fig (.\.20)

$\gamma = 10.0$

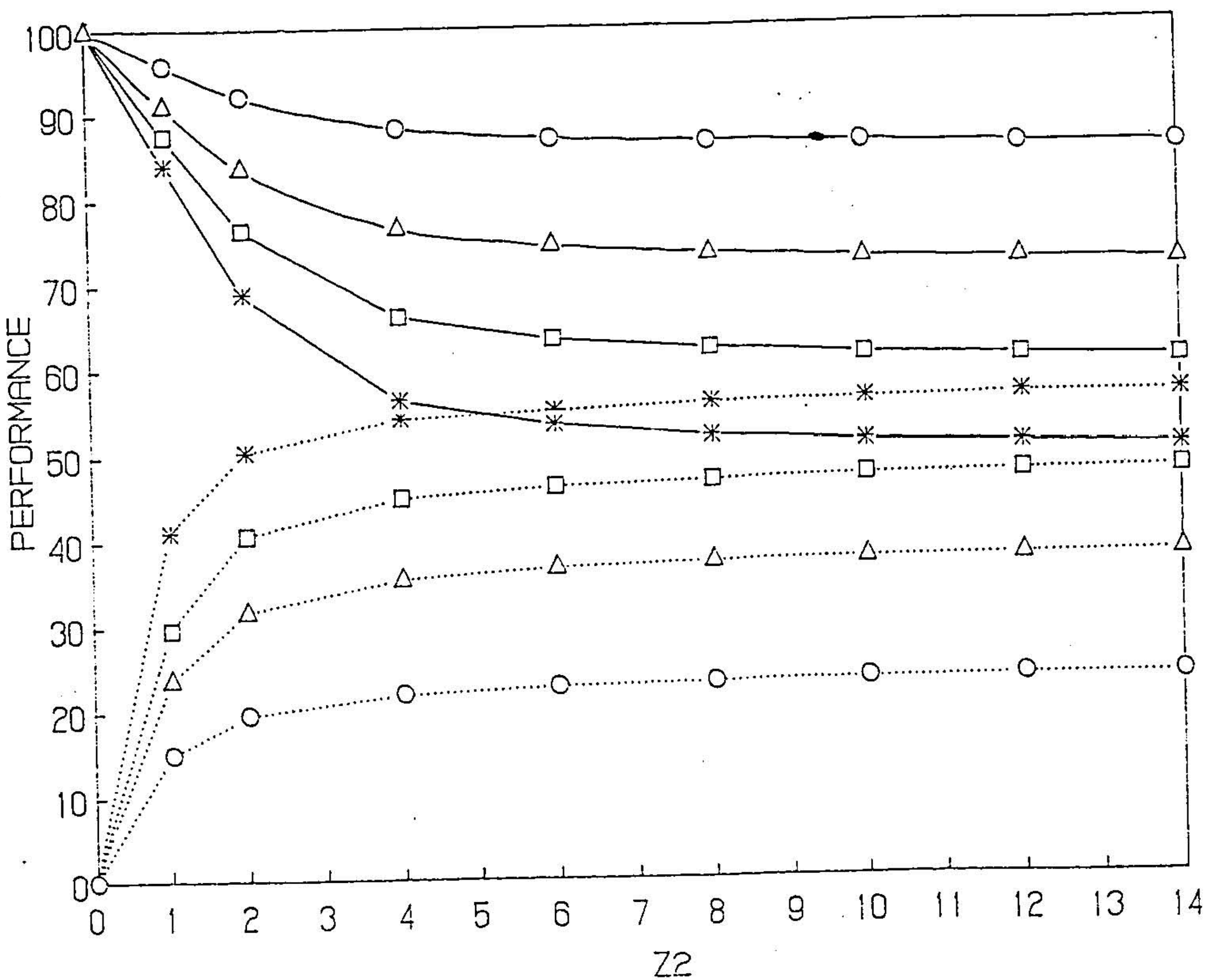


Fig (3.21)

γ = 30.0

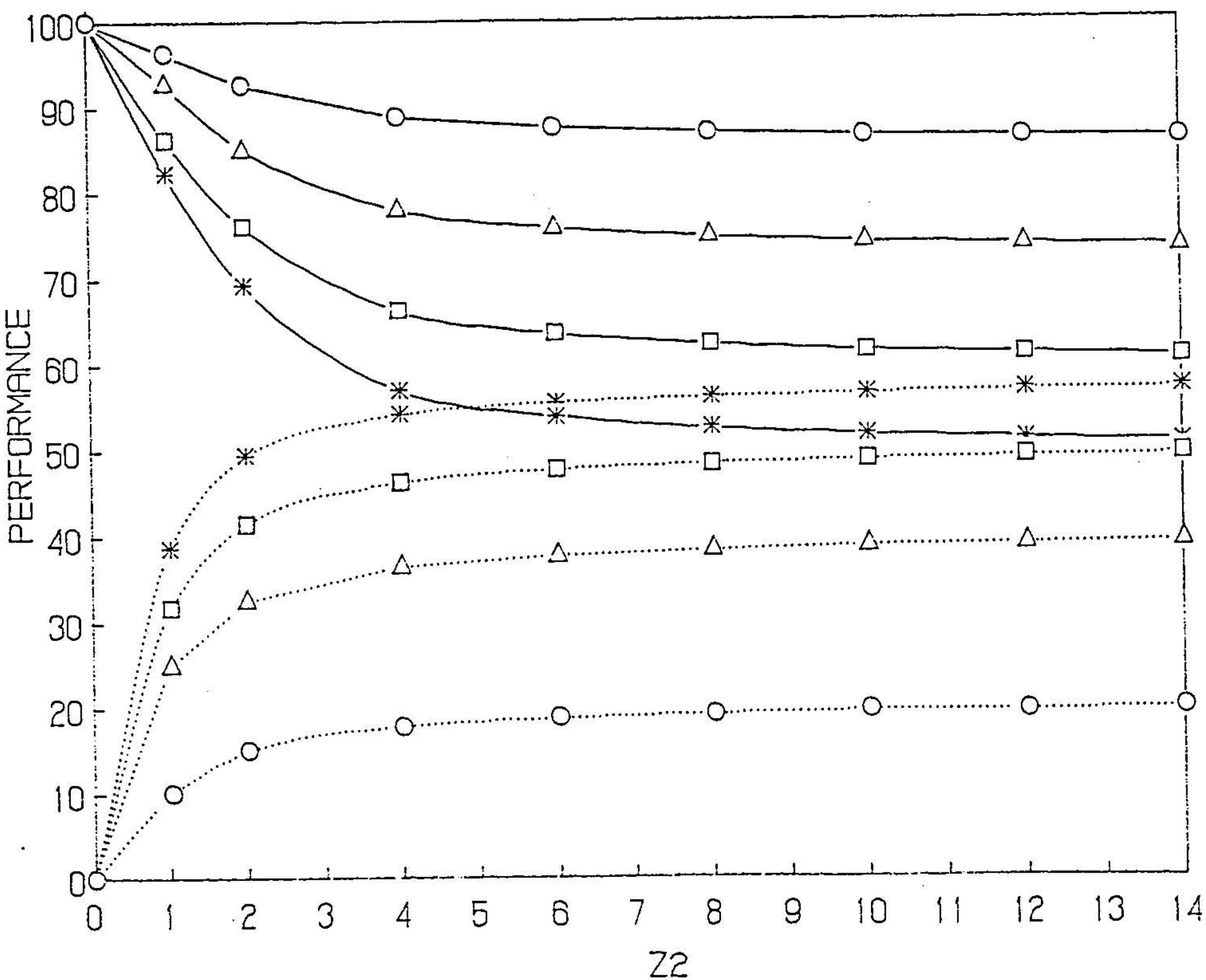

PERFORMANCE
0
10
20
30
40
50
60
70
80
90
100
Z2
0 1 2 3 4 5 6 7 8 9 10 11 12 13 14

Fig (3.23)

$\gamma = 40.0$

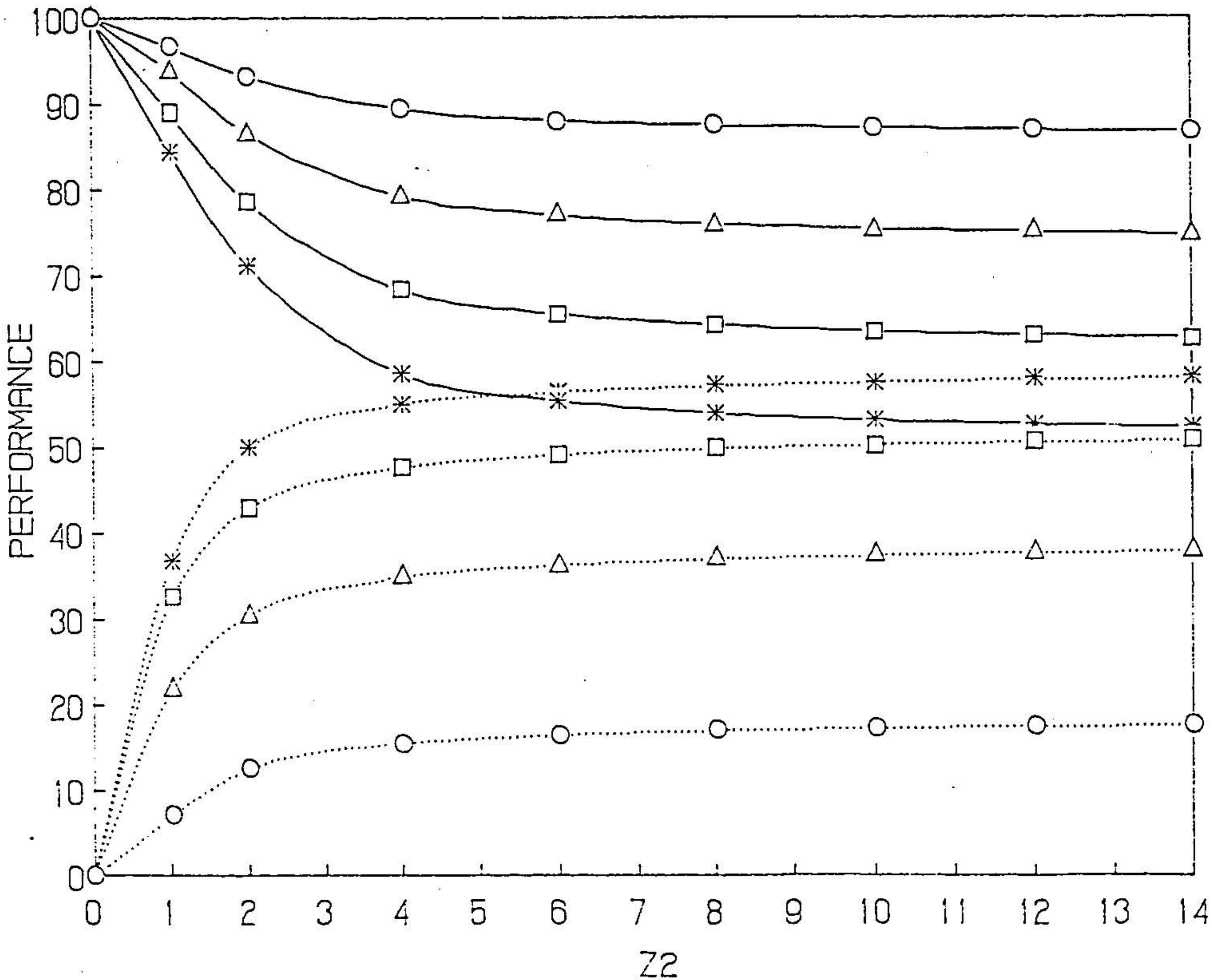


Fig (3.24)

$\gamma = 60.0$

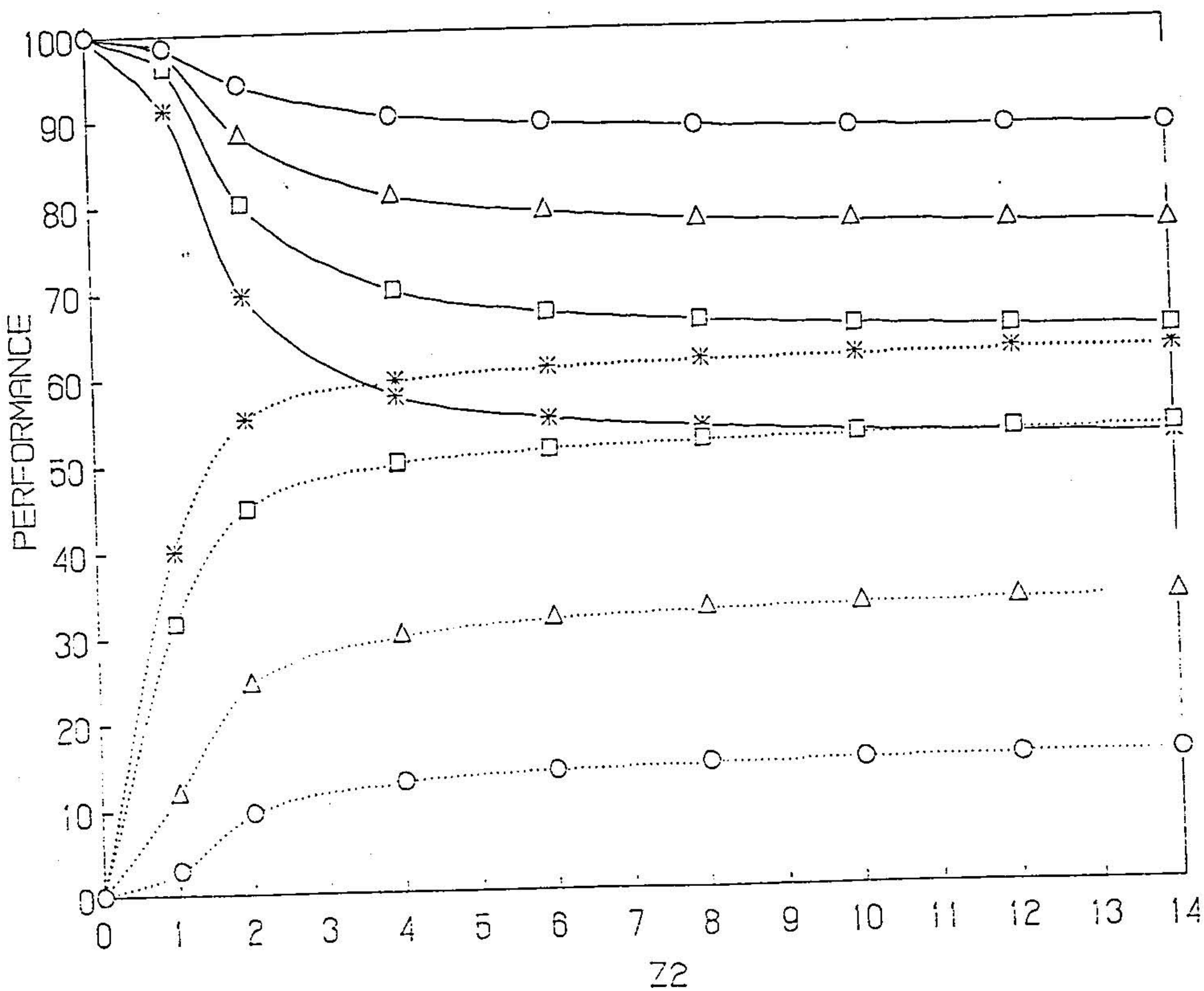


Fig (3.26)

$\gamma = 70.0$

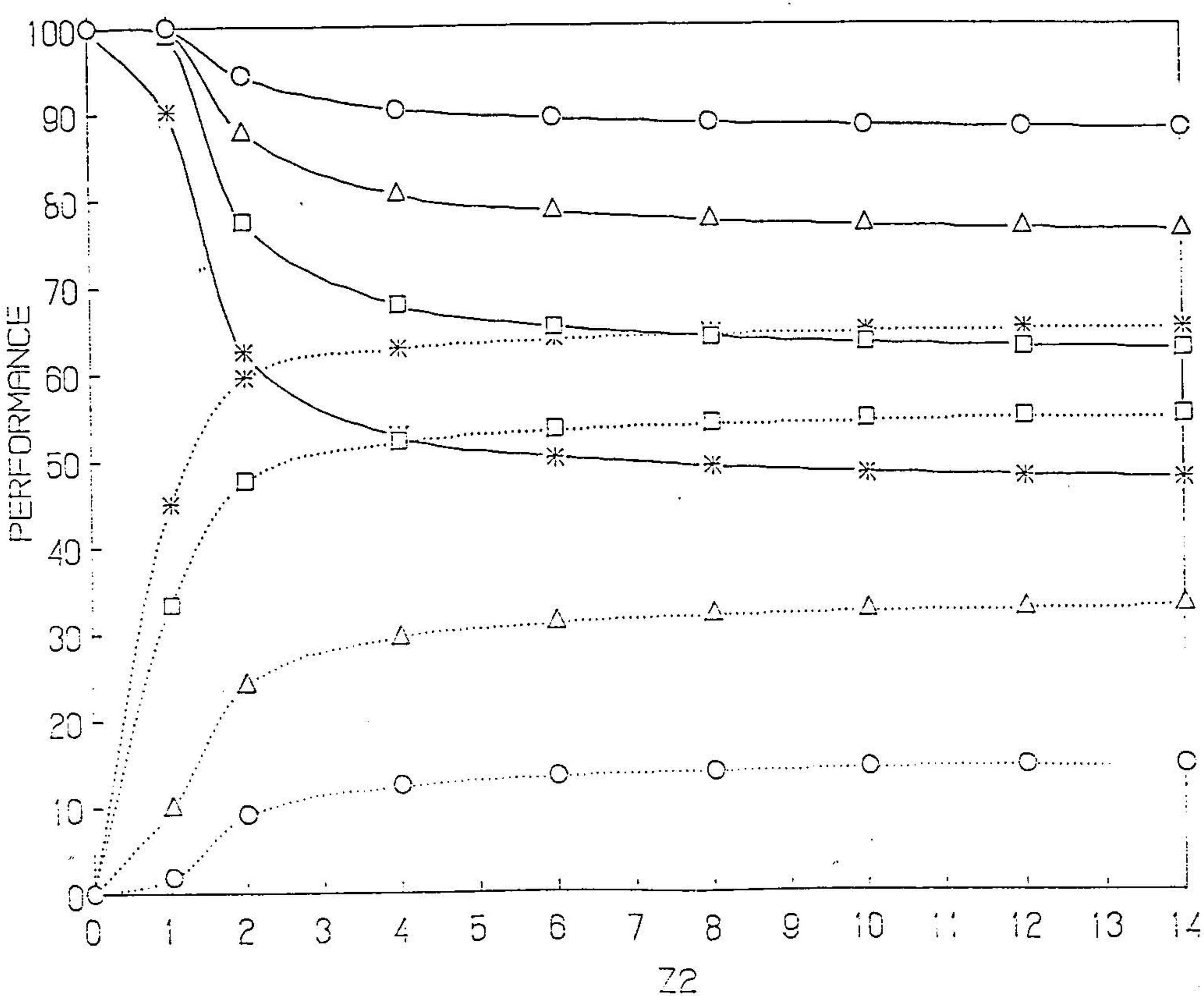


Fig (3.27)

$\gamma = 80.0$

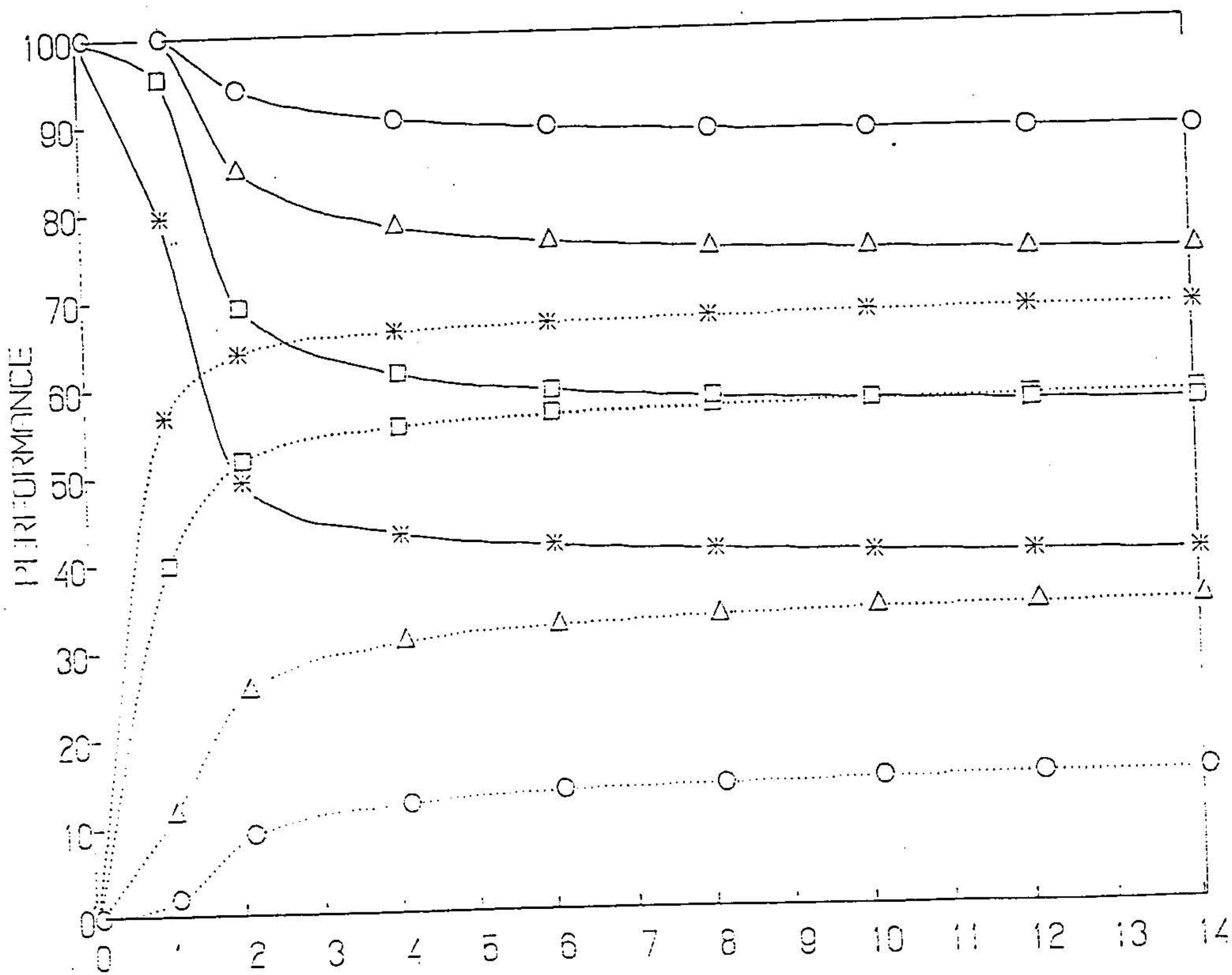


Fig (3.28)

$\gamma = 90.0$

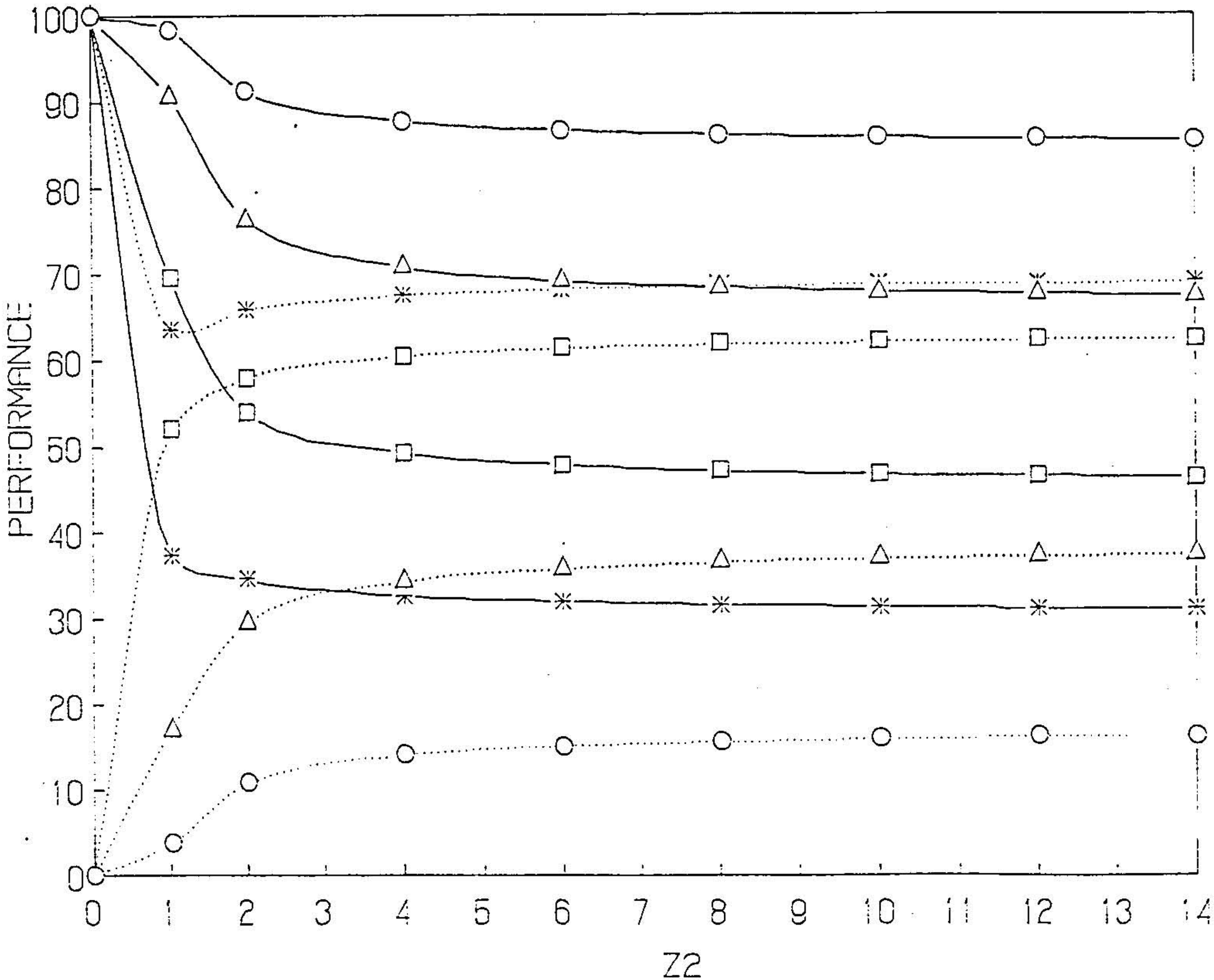


Fig (3.29)

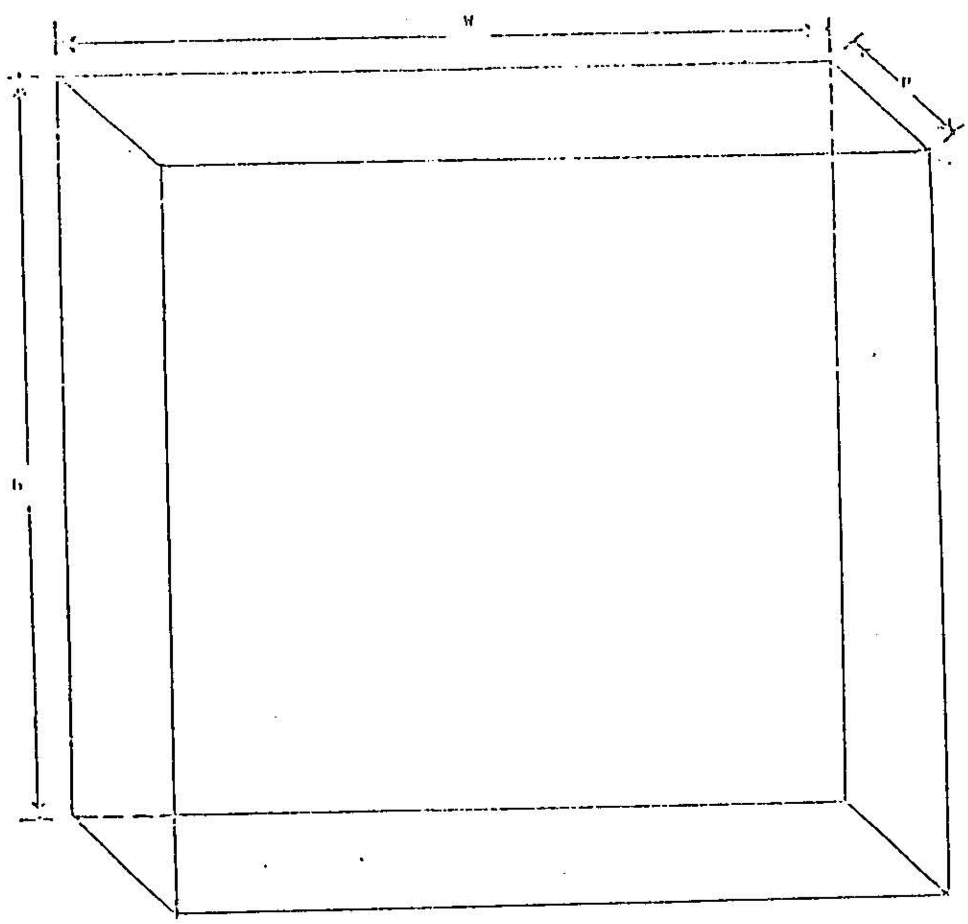
Summer and winter performances
curves for square eggcrate
shading window device in Jordan, Amman.

Fig (3.30)-Fig(3.48)

H = relative height = 1.0
W = relative width = 1.0

——O—— summeer performances

——Δ —— winter performances .



$\gamma = 0.0$

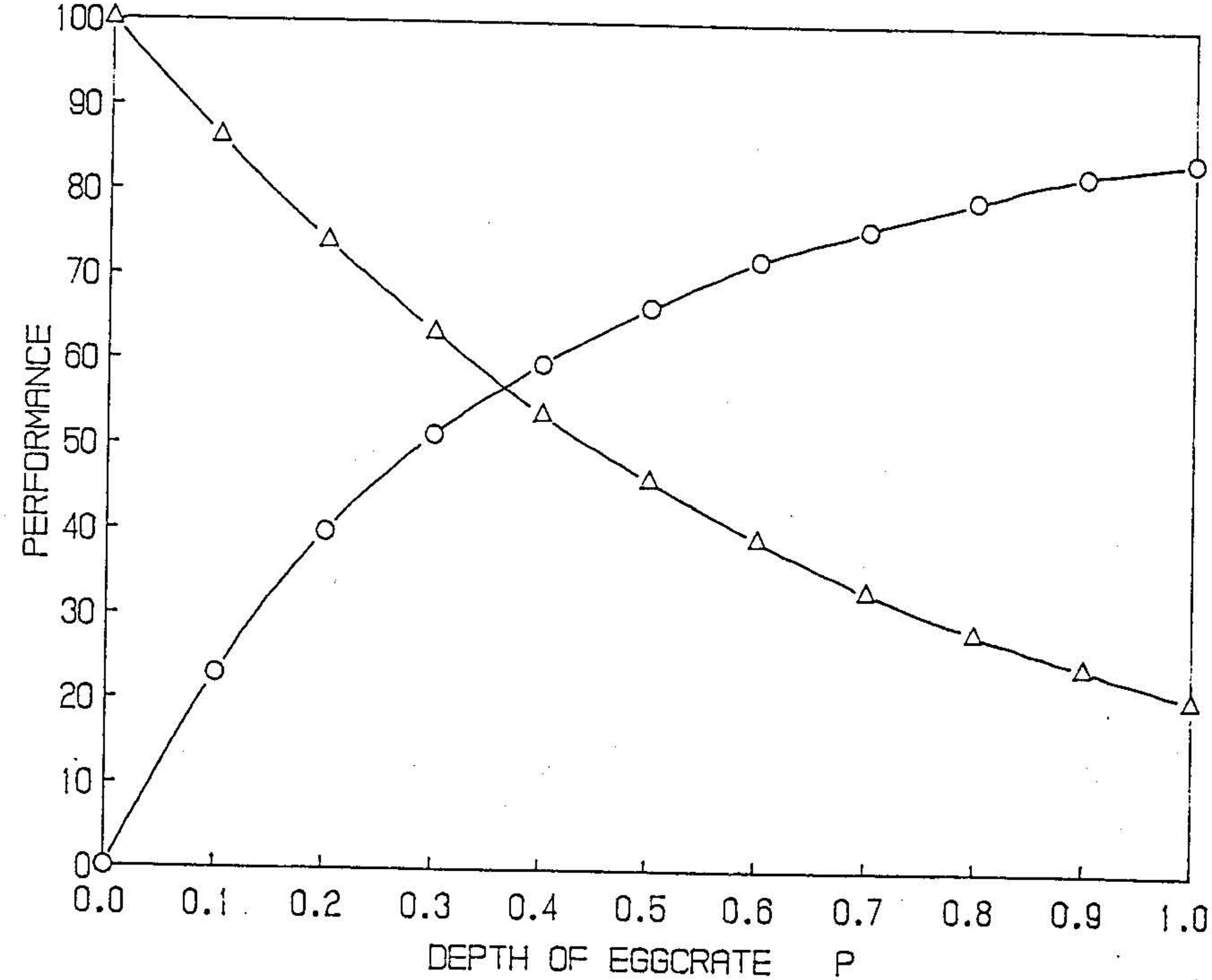


Fig (3.30)

$\gamma = 10.0$

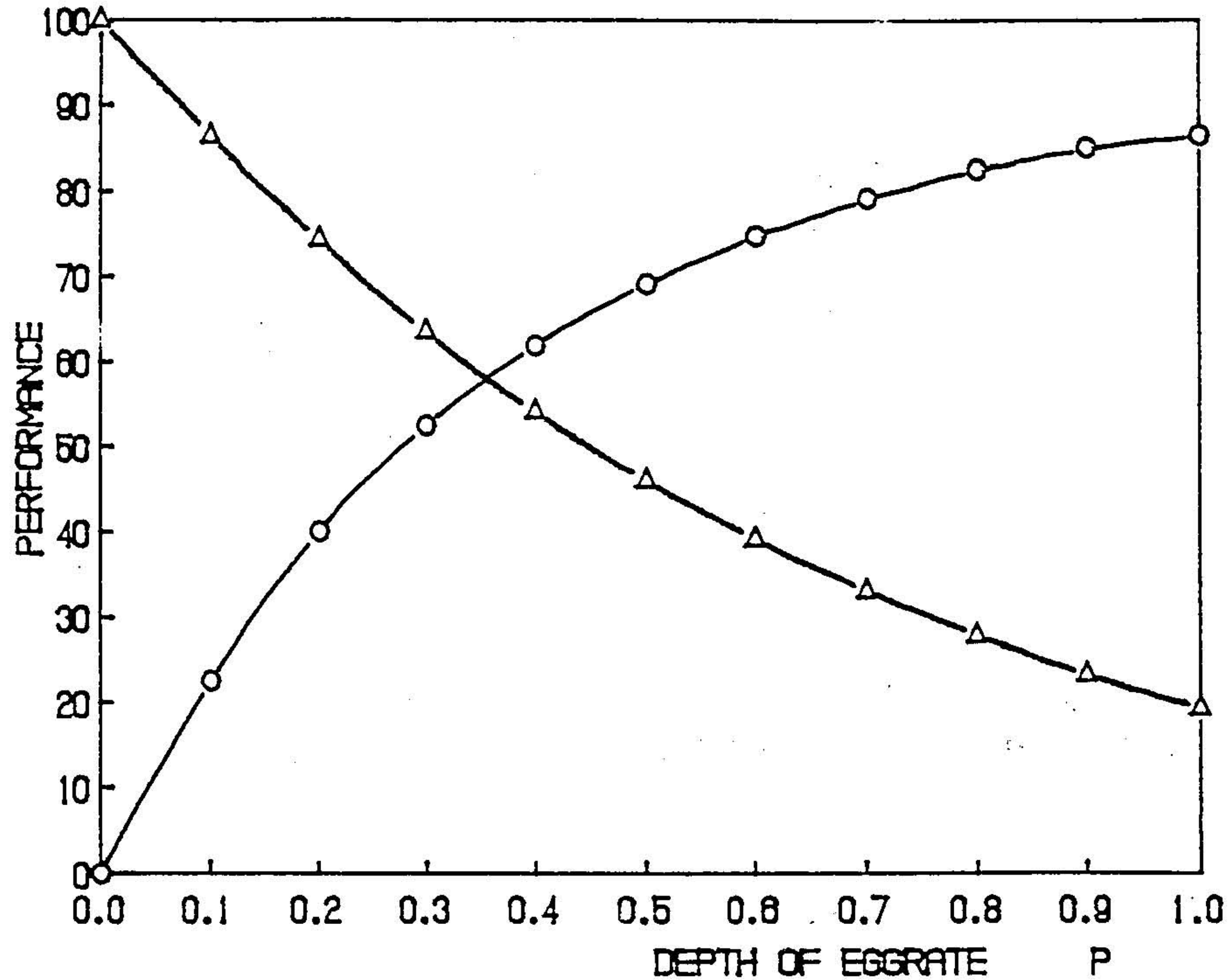


Fig (3.31)

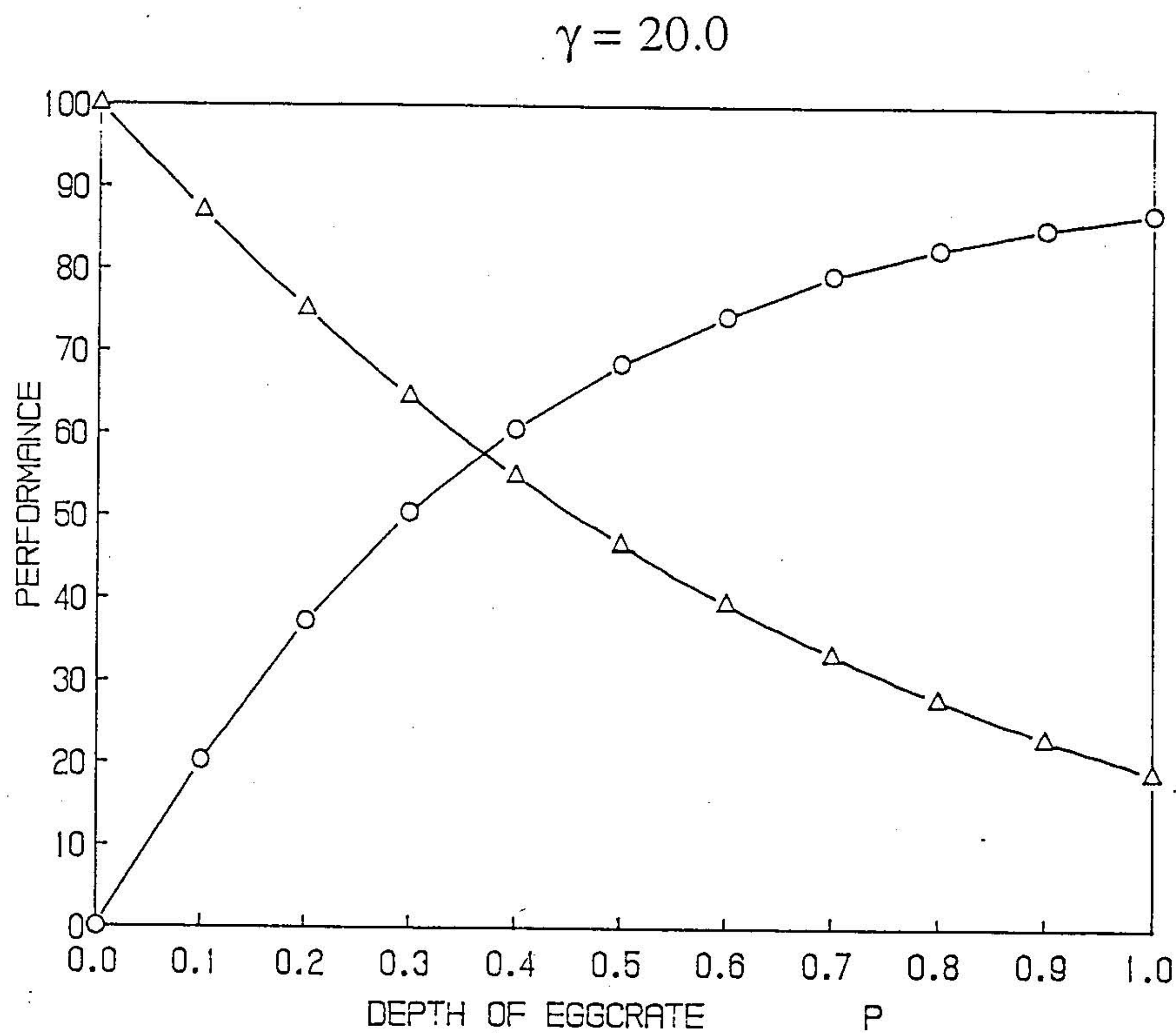

γ = 20.0
PERFORMANCE
0 10 20 30 40 50 60 70 80 90 100
0.0 0.1 0.2 0.3 0.4 0.5 0.6 0.7 0.8 0.9 1.0
DEPTH OF EGGCRATE P

Fig (3.32)

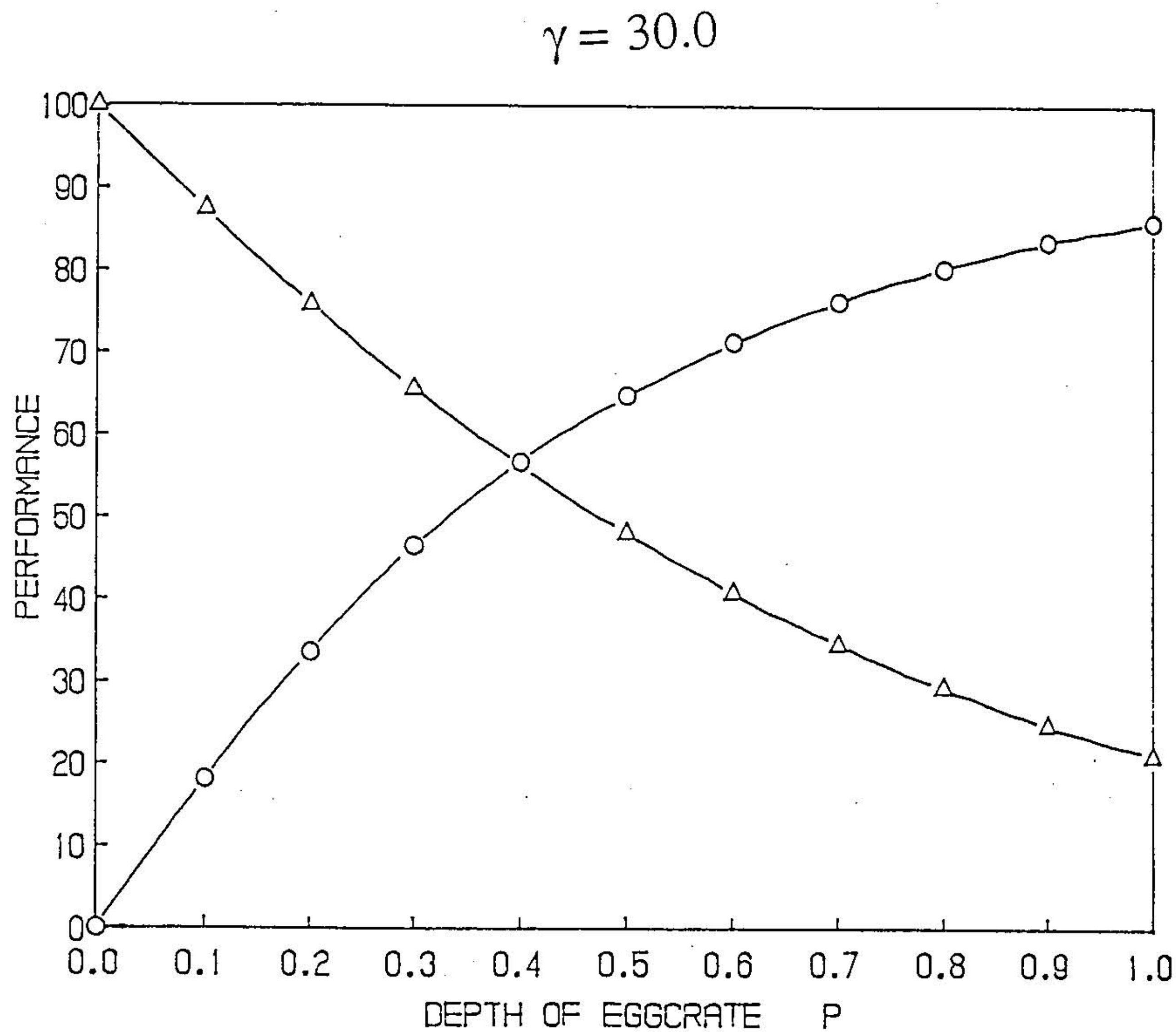

γ = 30.0
PERFORMANCE
100
90
80
70
60
50
40
30
20
10
0
0.0
0.1
0.2
0.3
0.4
0.5
0.6
0.7
0.8
0.9
1.0
DEPTH OF EGGCRATE P

Fig (3.33)

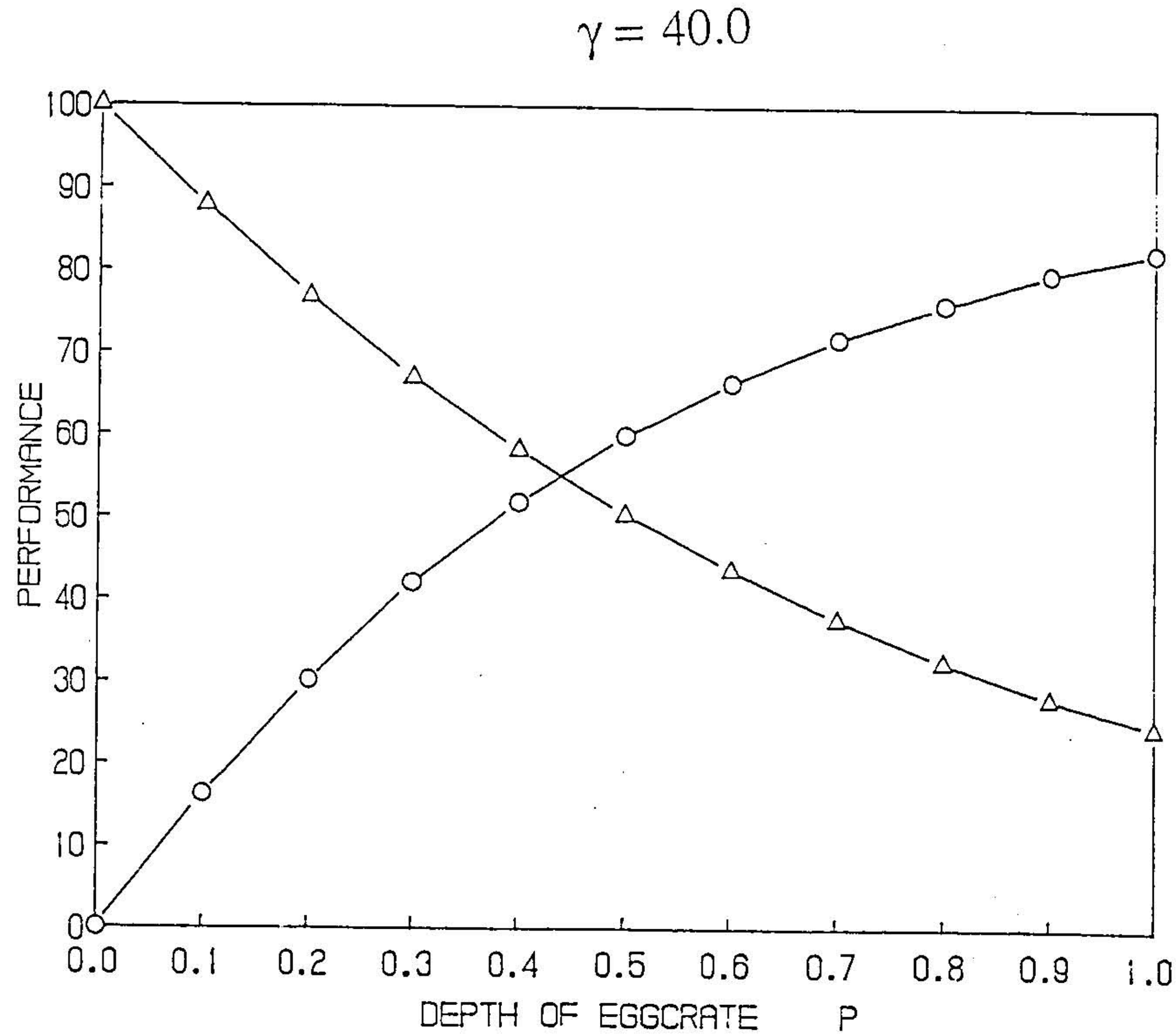

γ = 40.0
PERFORMANCE
100
90
80
70
60
50
40
30
20
10
0
0.0
0.1
0.2
0.3
0.4
0.5
0.6
0.7
0.8
0.9
1.0
DEPTH OF EGGCRATE P

Fig (3.34)

$\gamma = 50.0$

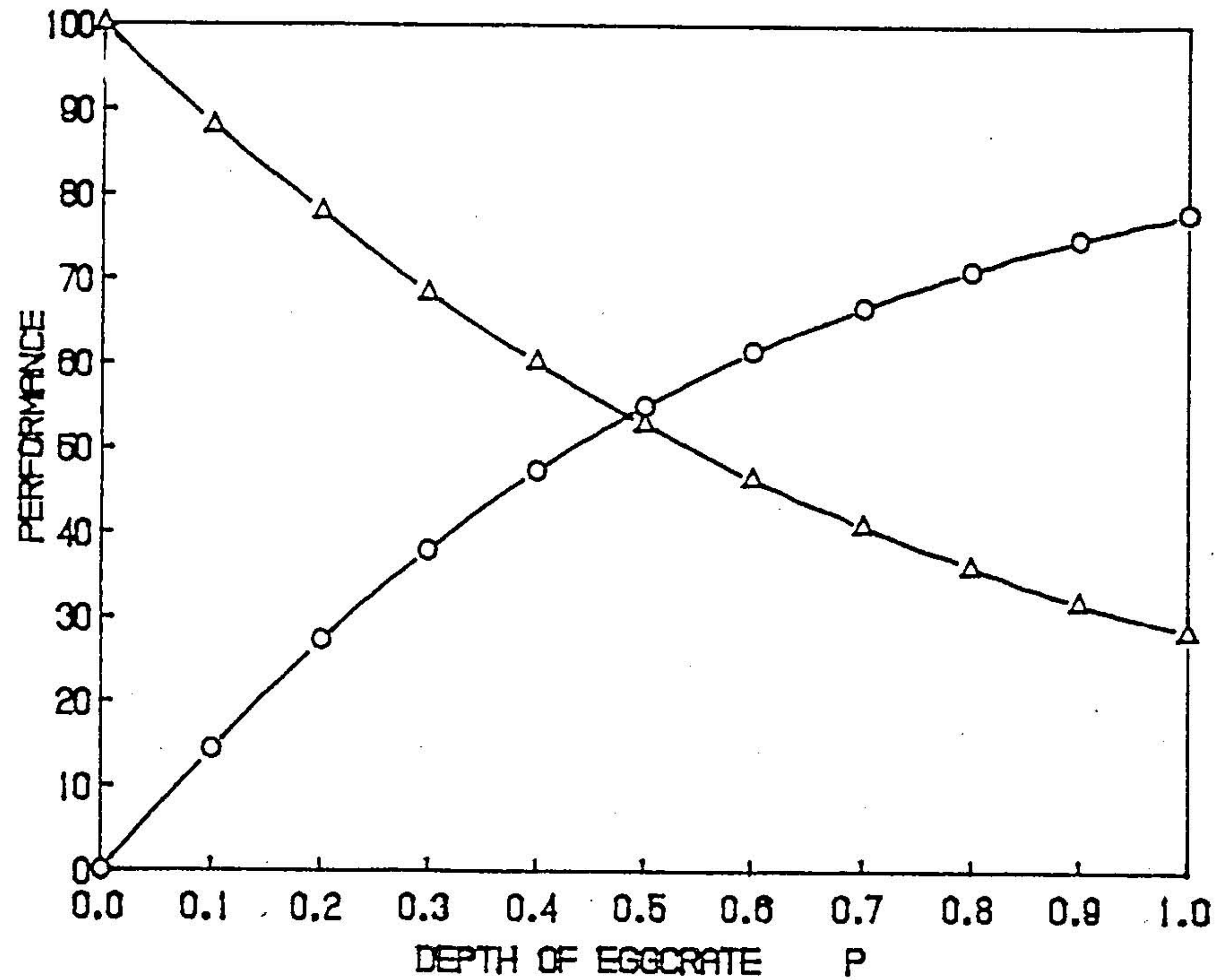


Fig (3.35)

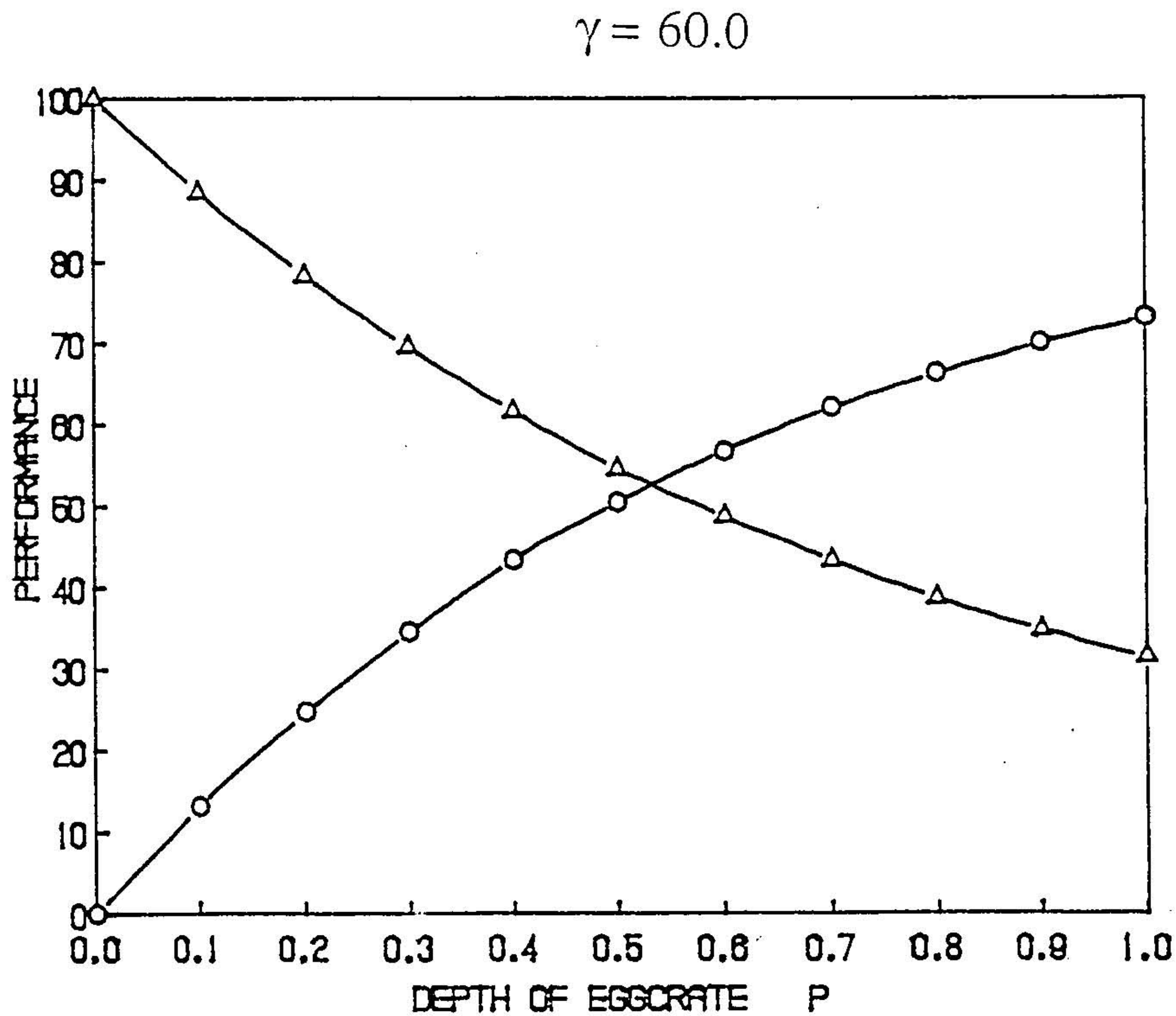

γ = 60.0
PERFORMANCE
100
90
80
70
60
50
40
30
20
10
0
0.0
0.1
0.2
0.3
0.4
0.5
0.6
0.7
0.8
0.9
1.0
DEPTH OF EGGCRATE P

Fig (3.36)

$\gamma = 70.0$

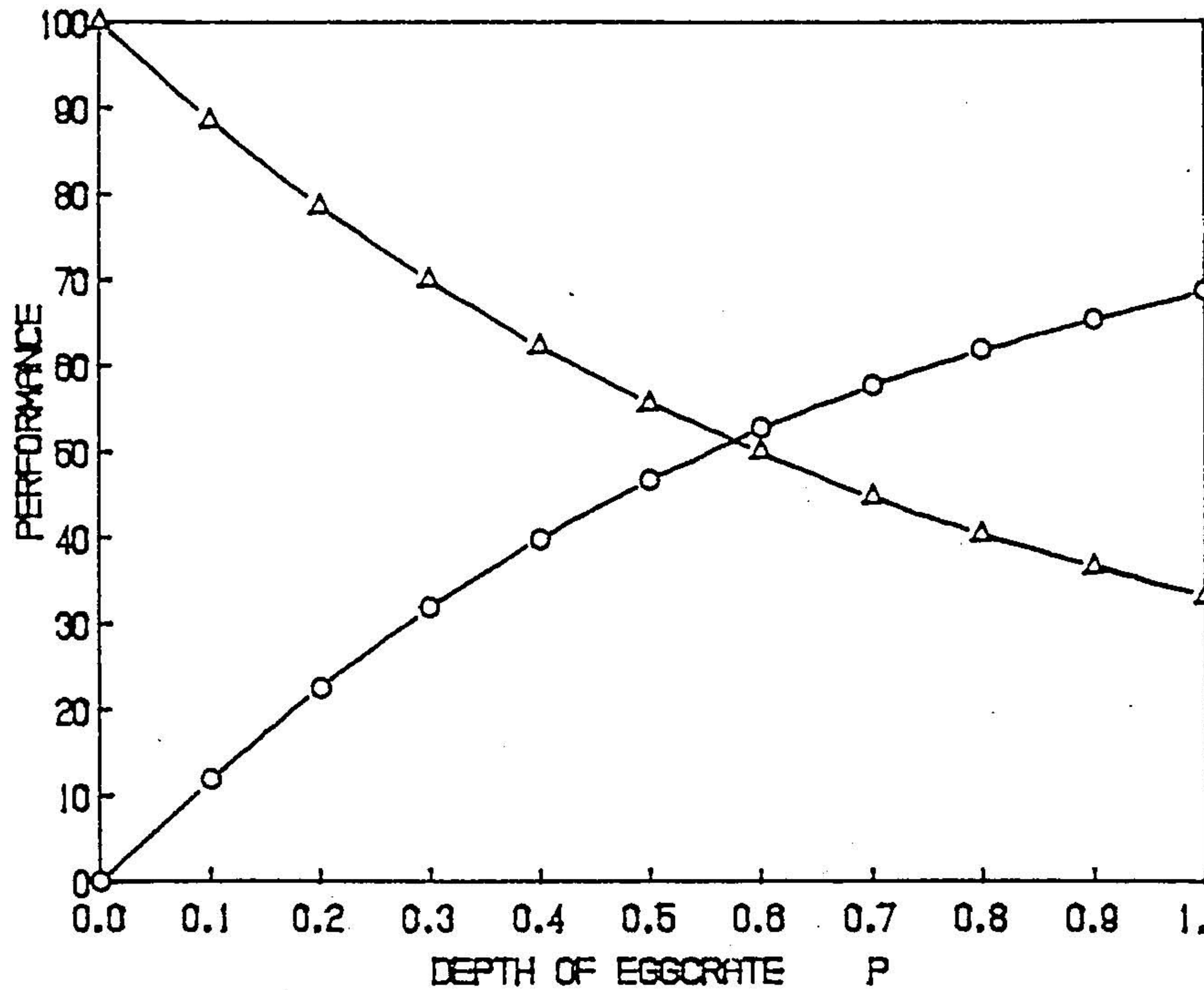


Fig (3.37)

$\gamma = 80.0$

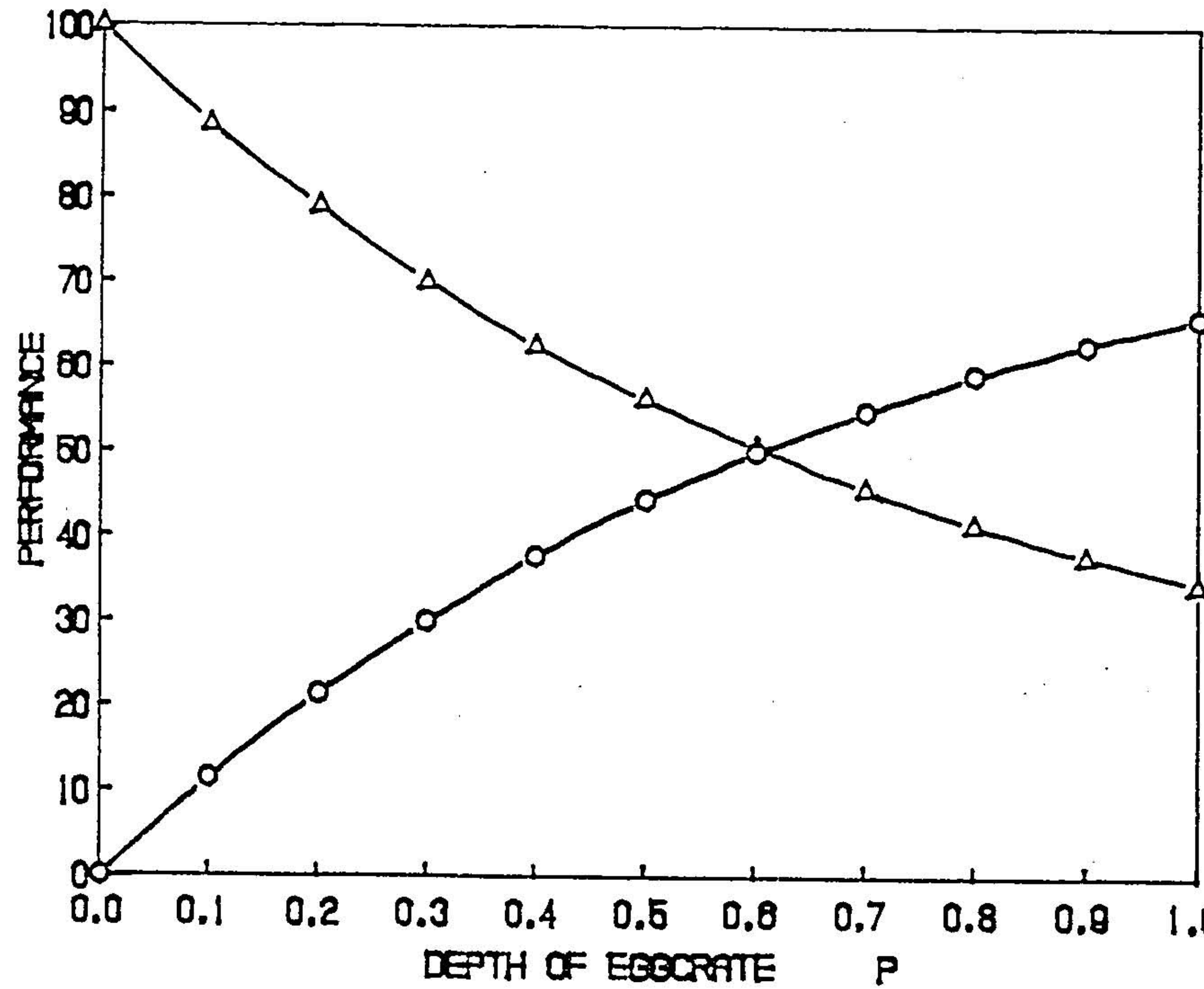


Fig (3.38)

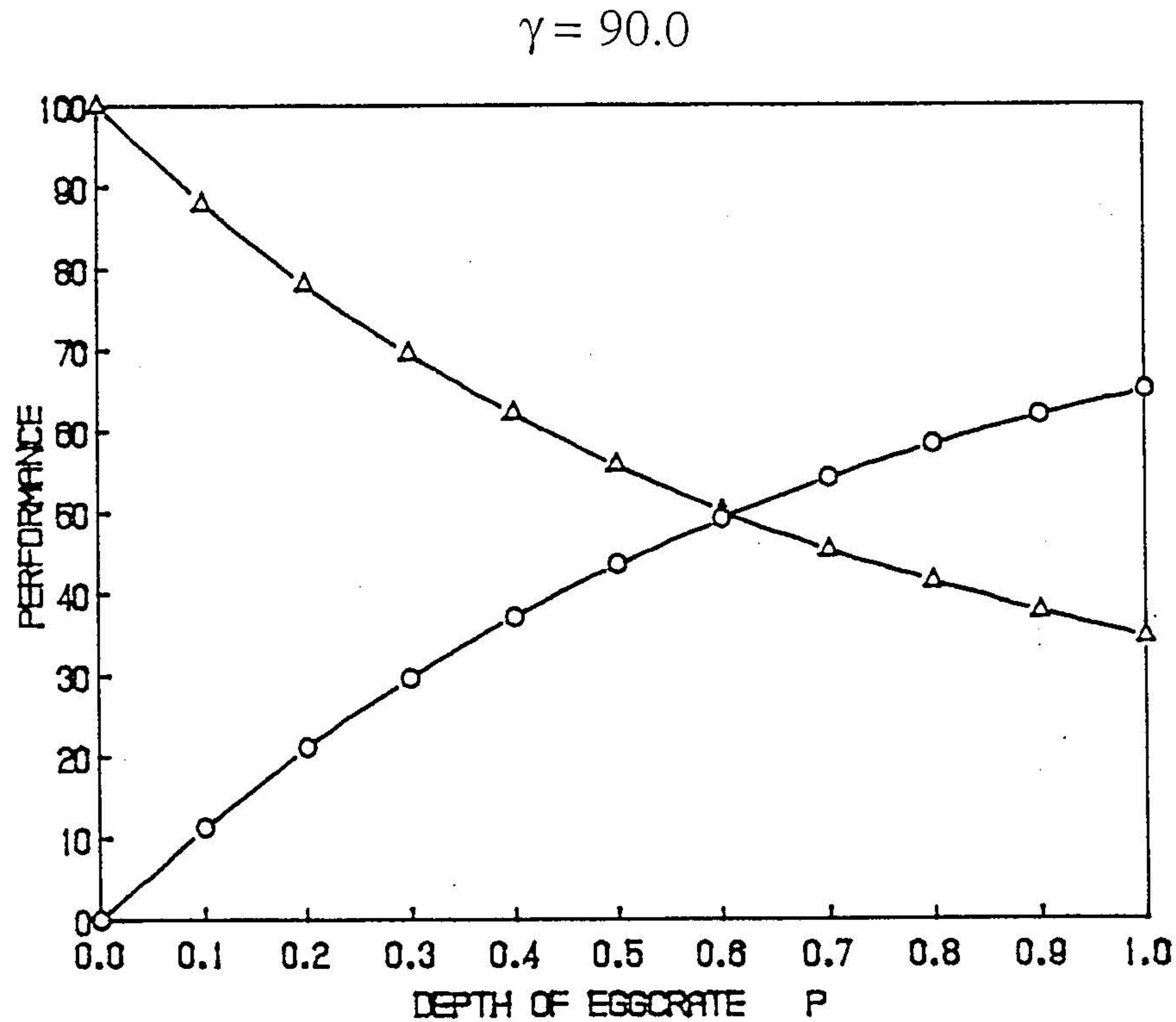

γ = 90.0
100
90
80
70
60
50
40
30
20
10
0
PERFORMANCE
0.0
0.1
0.2
0.3
0.4
0.5
0.6
0.7
0.8
0.9
1.0
DEPTH OF EGGCRATE P

Fig (3.39)

$\gamma = 100.0$

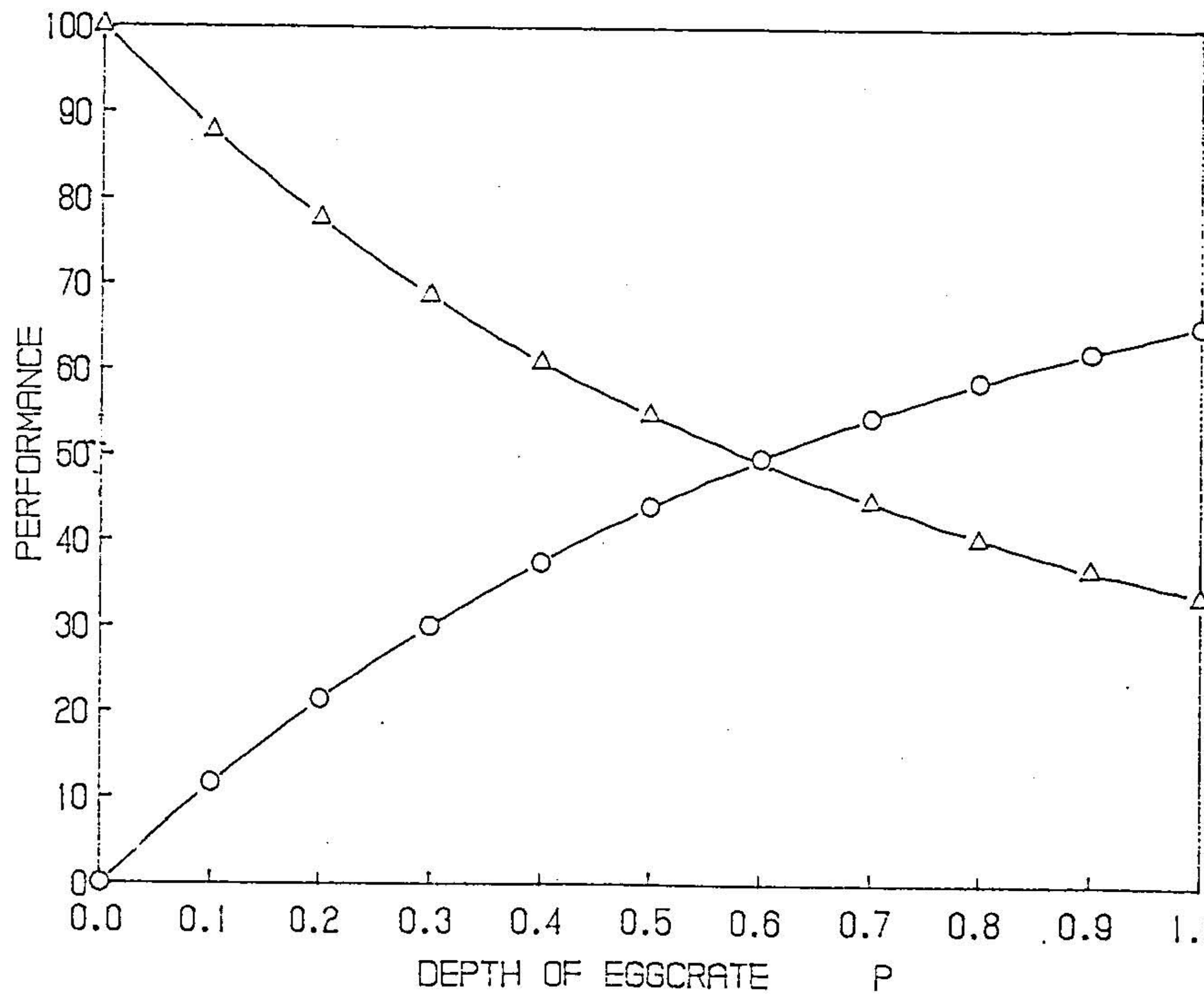


Fig (3.40)

$\gamma = 110.0$

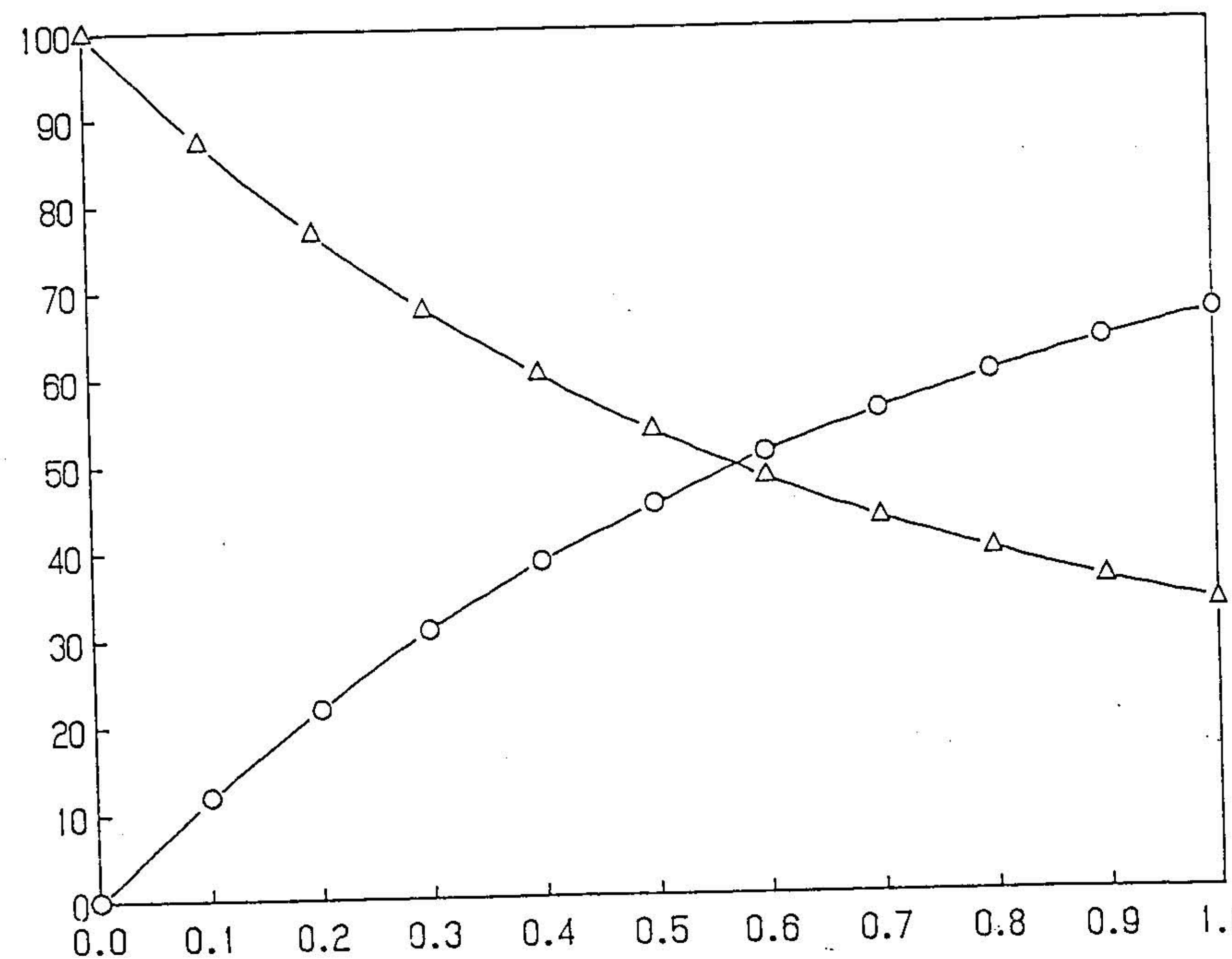


Fig (3.41)

$\gamma = 120.0$

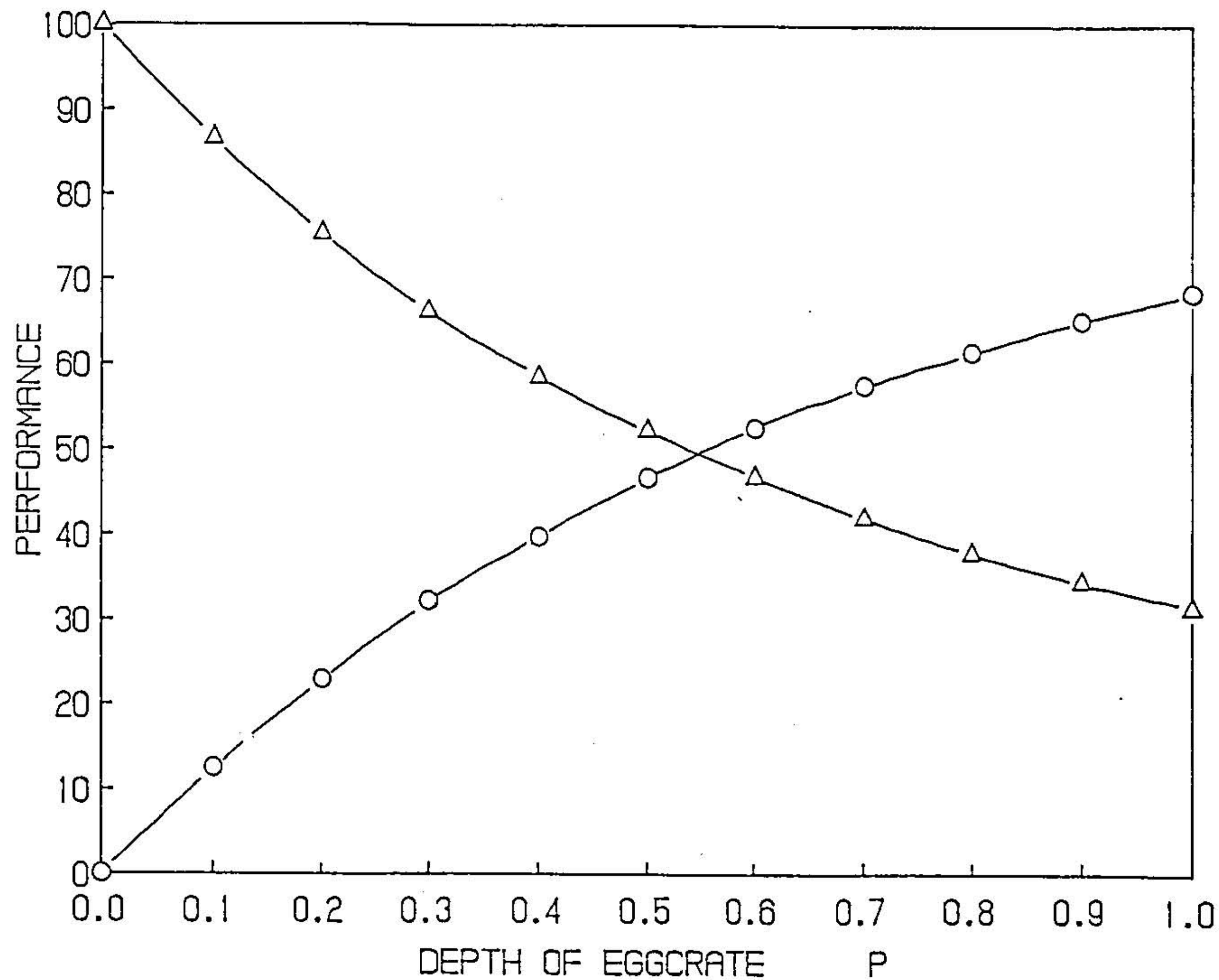


Fig (3.42)

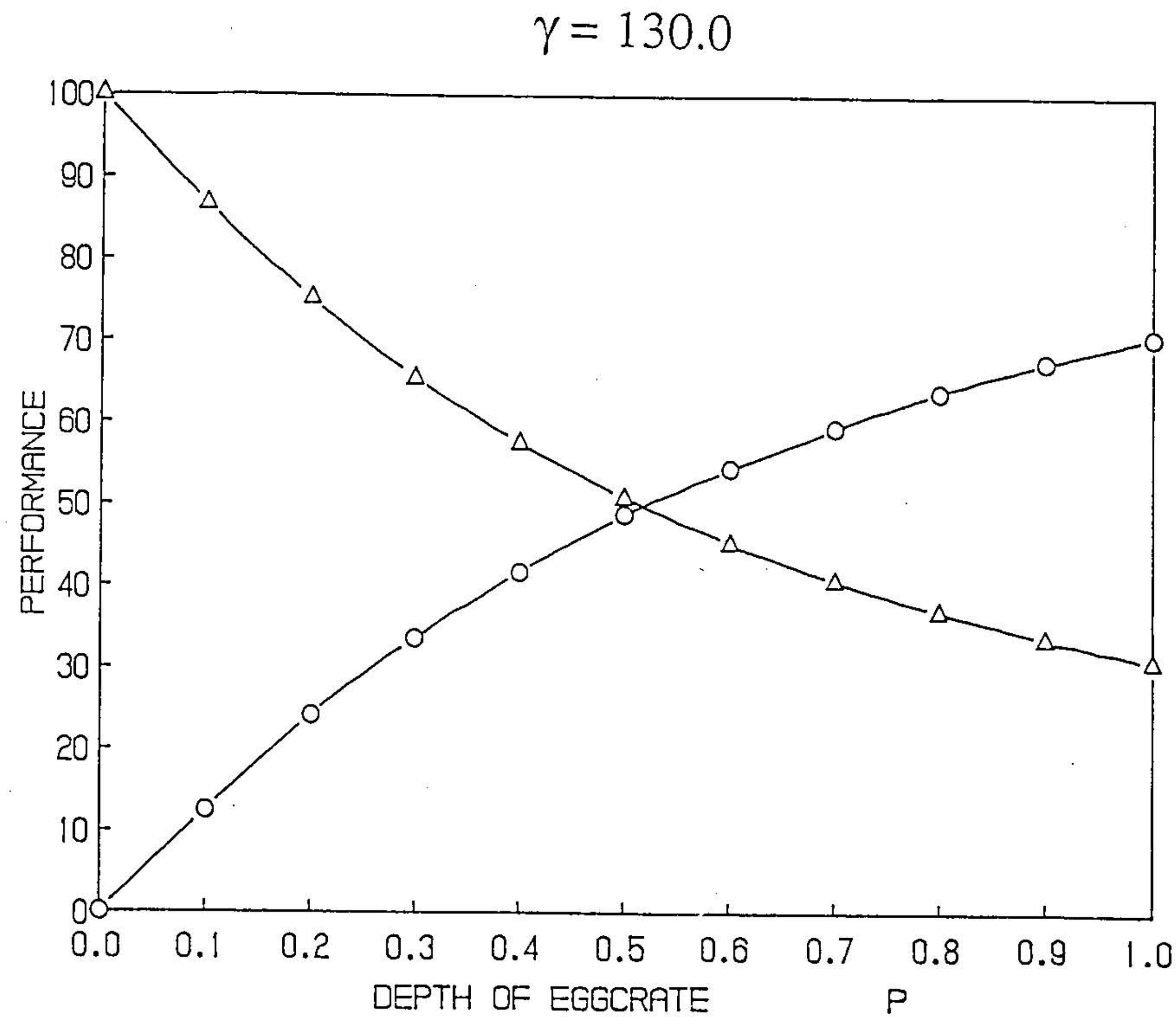

γ = 130.0
PERFORMANCE
100
90
80
70
60
50
40
30
20
10
0
0.0
0.1
0.2
0.3
0.4
0.5
0.6
0.7
0.8
0.9
1.0
DEPTH OF EGGCRATE
P

Fig (3.43)

$\gamma = 150.0$

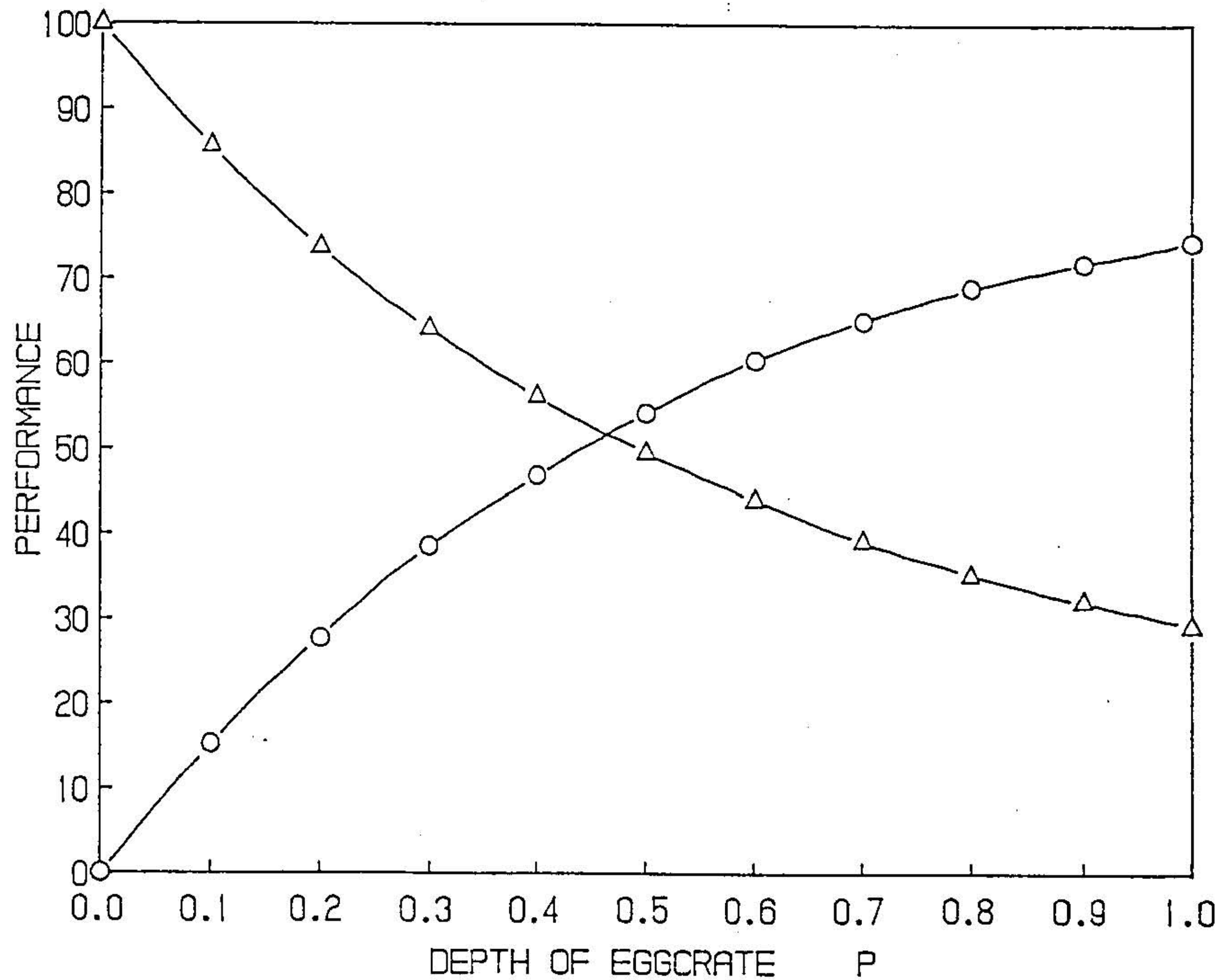


Fig (3.45)

$\gamma = 160.0$

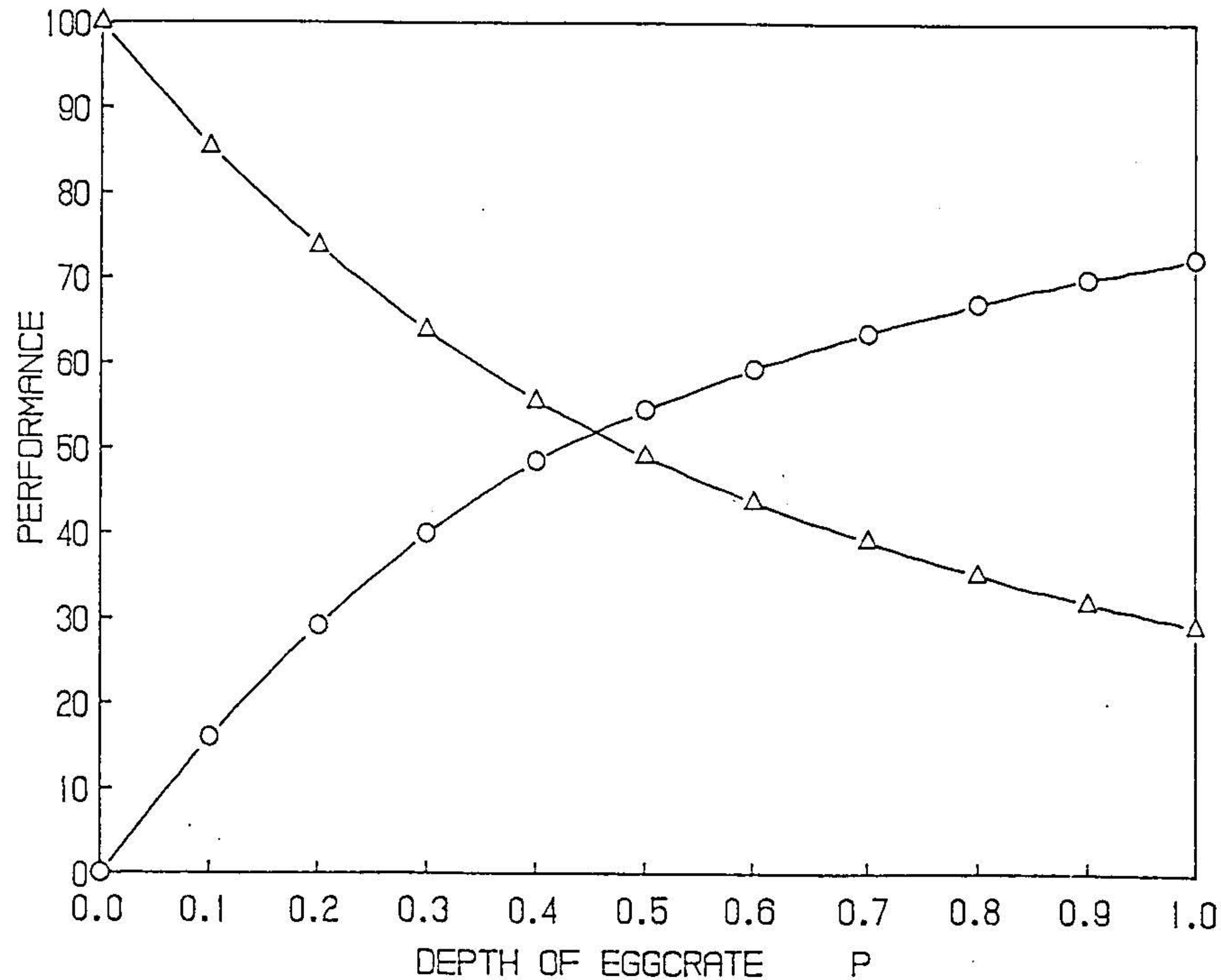


Fig (3.46)

$\gamma = 170.0$

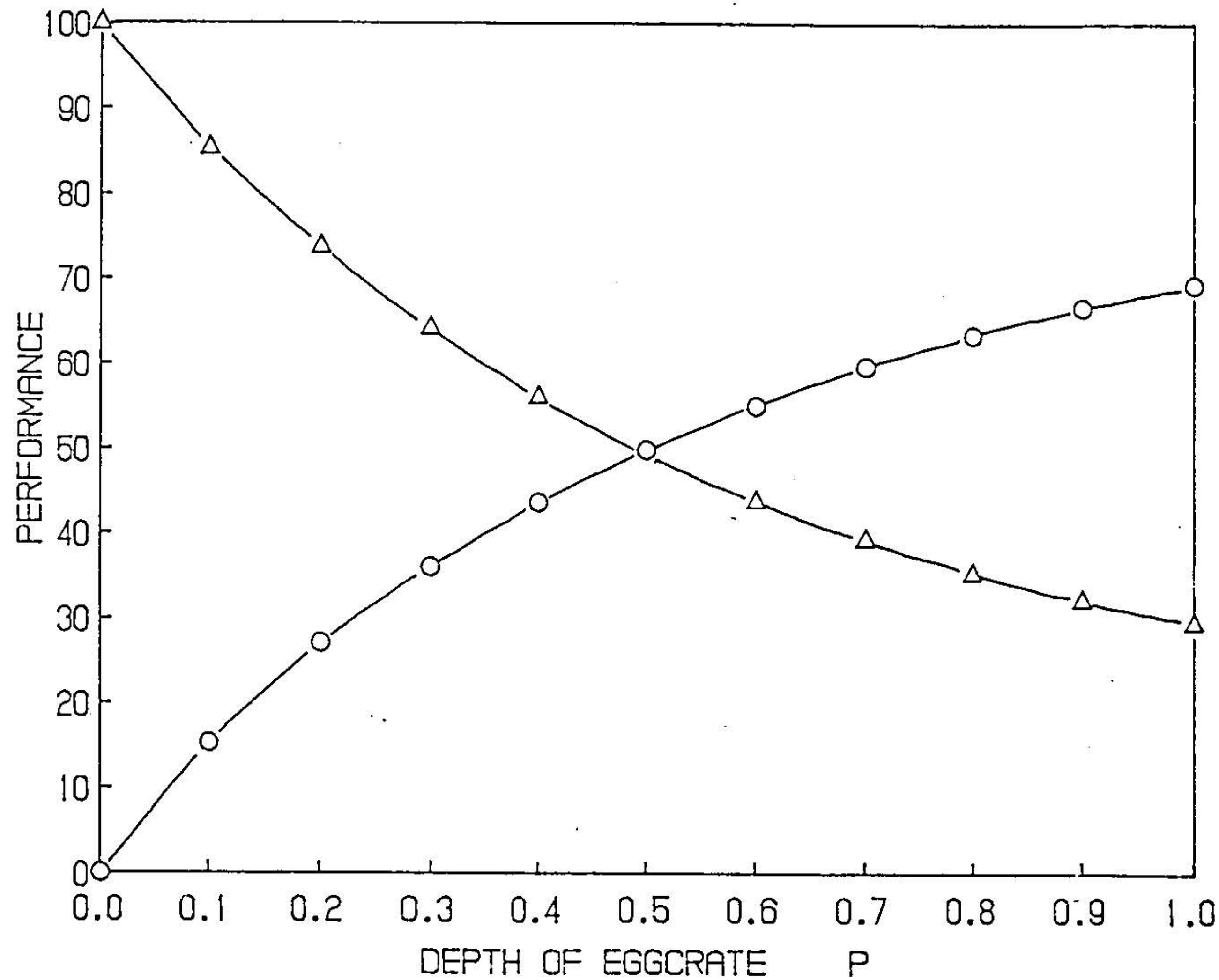


Fig (3.47)

$\gamma = 180.0$

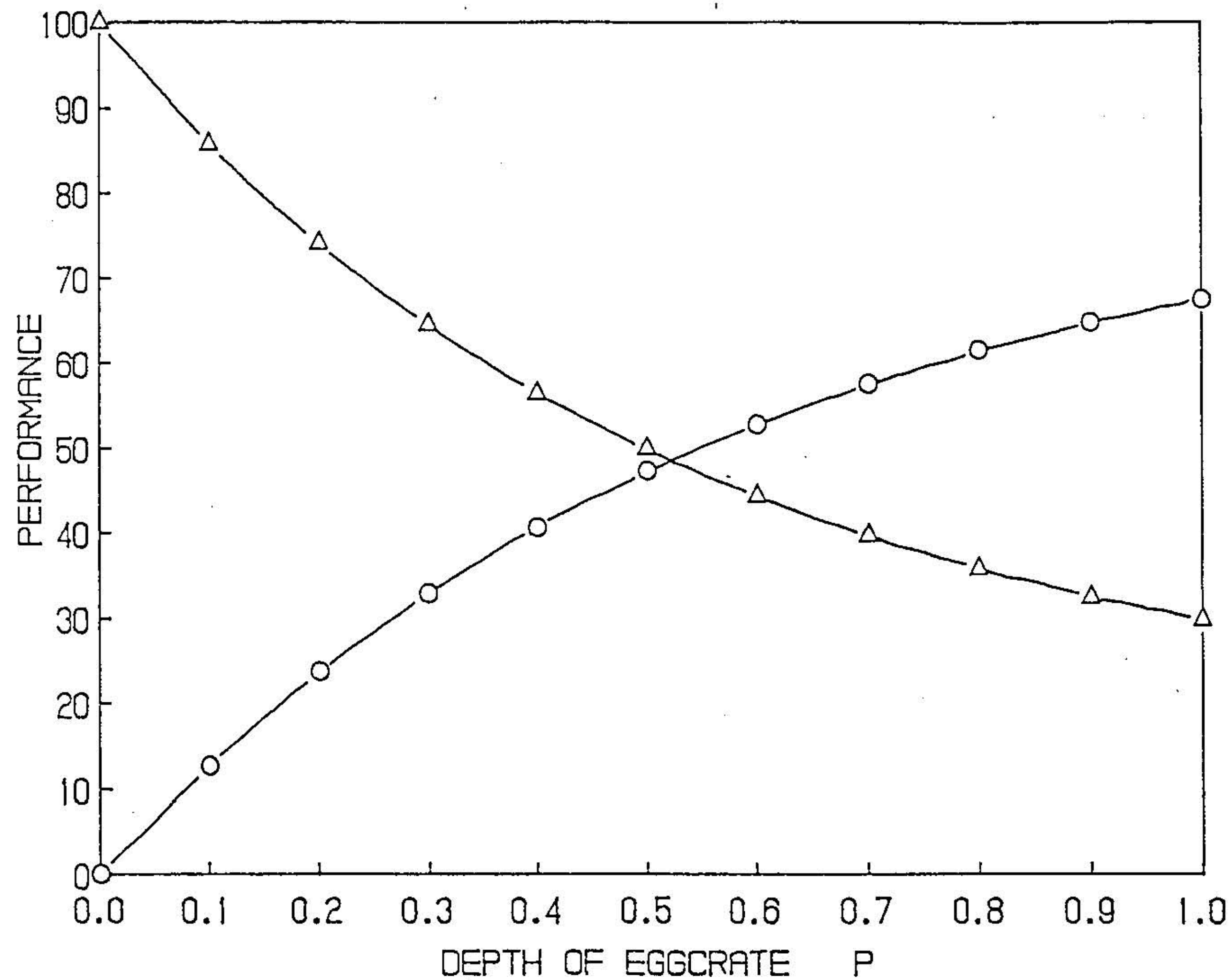


Fig (3.48)

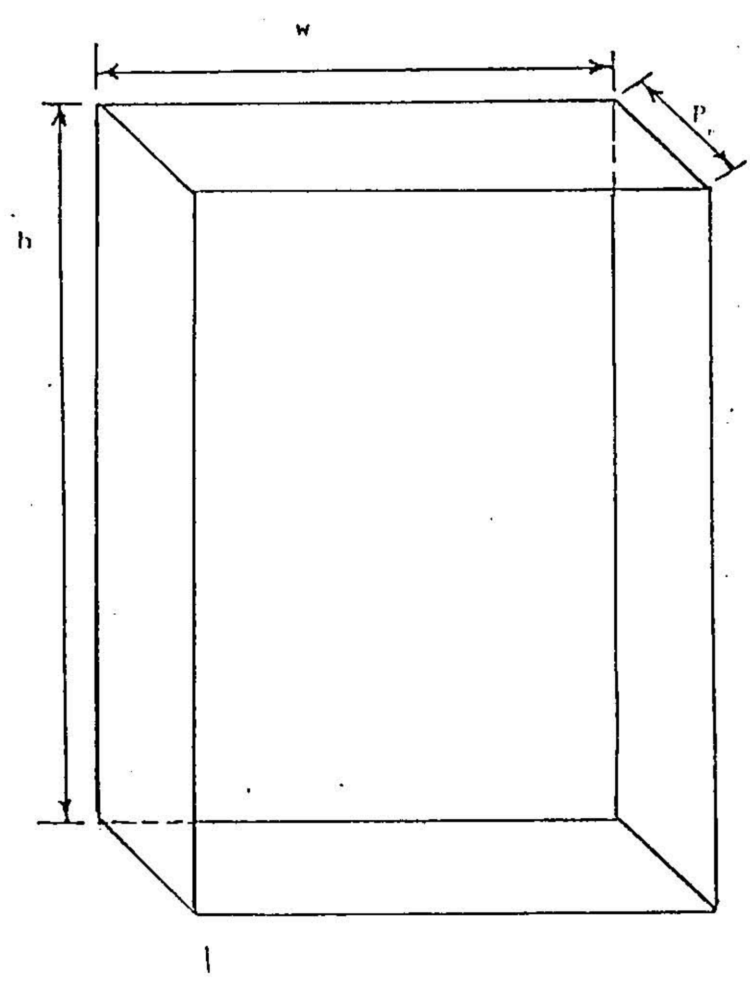
Summer and winter performances
curves for vertical eggcrate
shading window devices in Jordan

Fig (3.49) - Fig (3.67)

W = relative width = 0.25
H = relative height = 4.0

——O—— summer performances

——□—— winter performances .



$\gamma = 0.0$

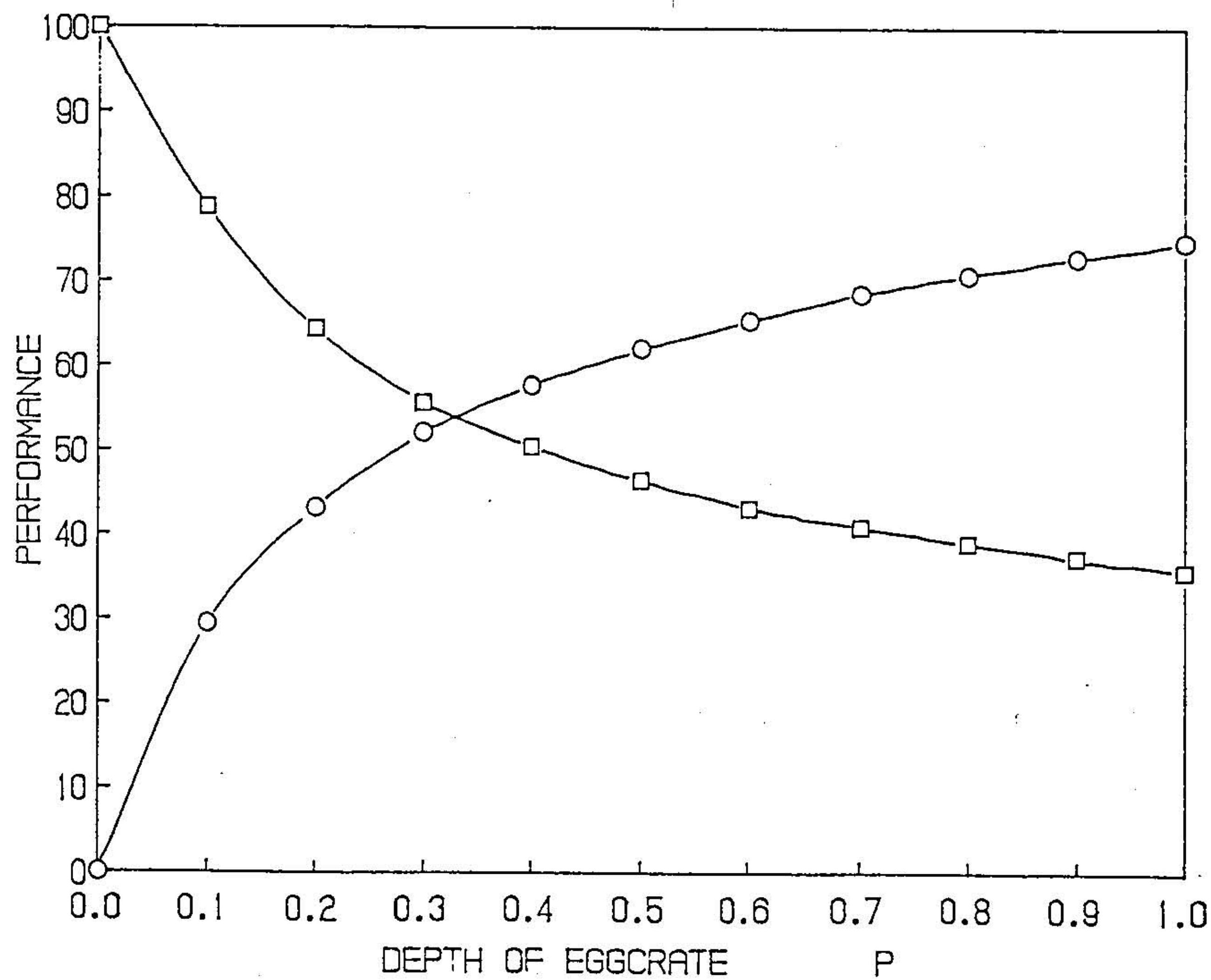


Fig (3.49)

$\gamma = 10.0$

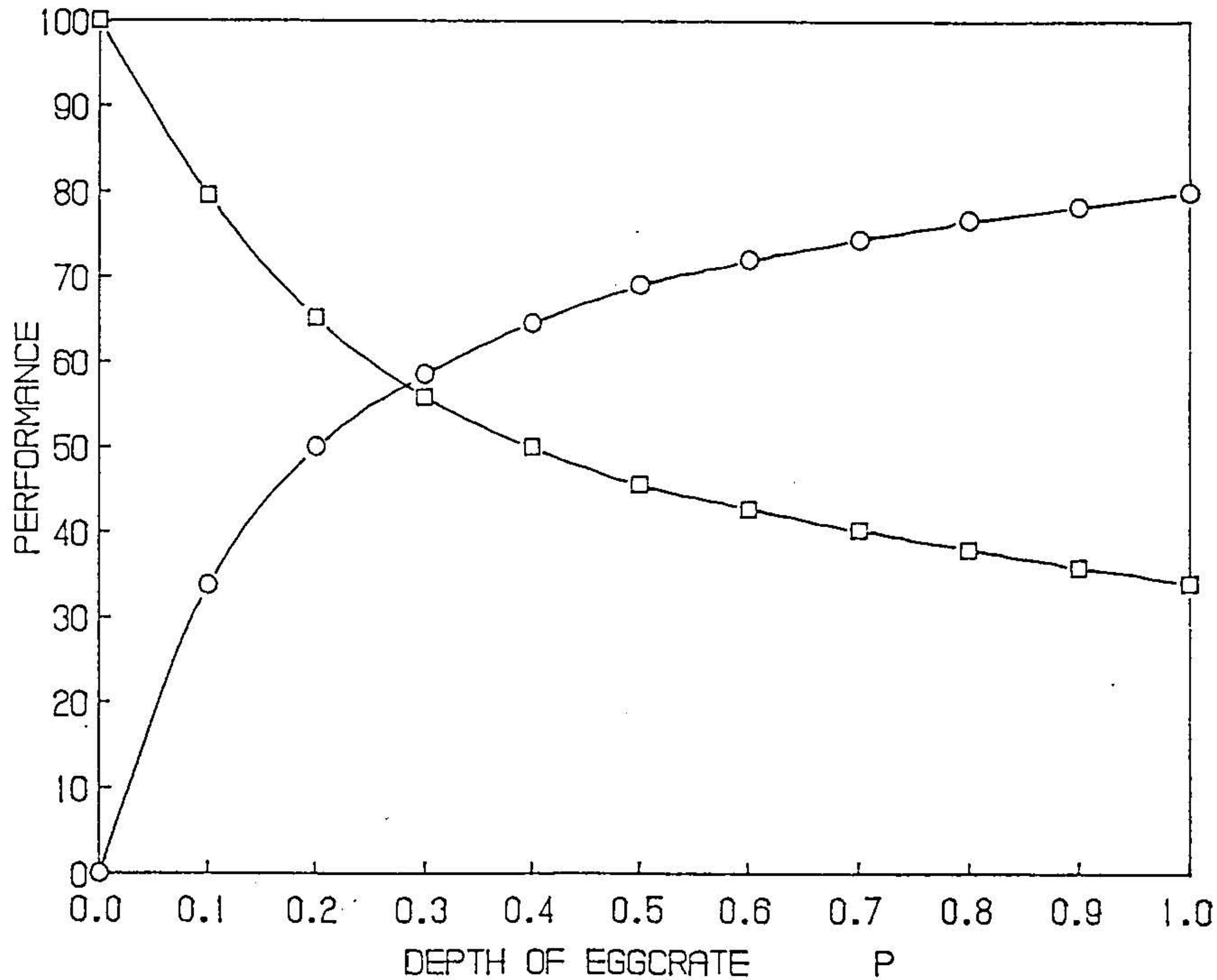


Fig (3.50)

$\gamma = 20.0$

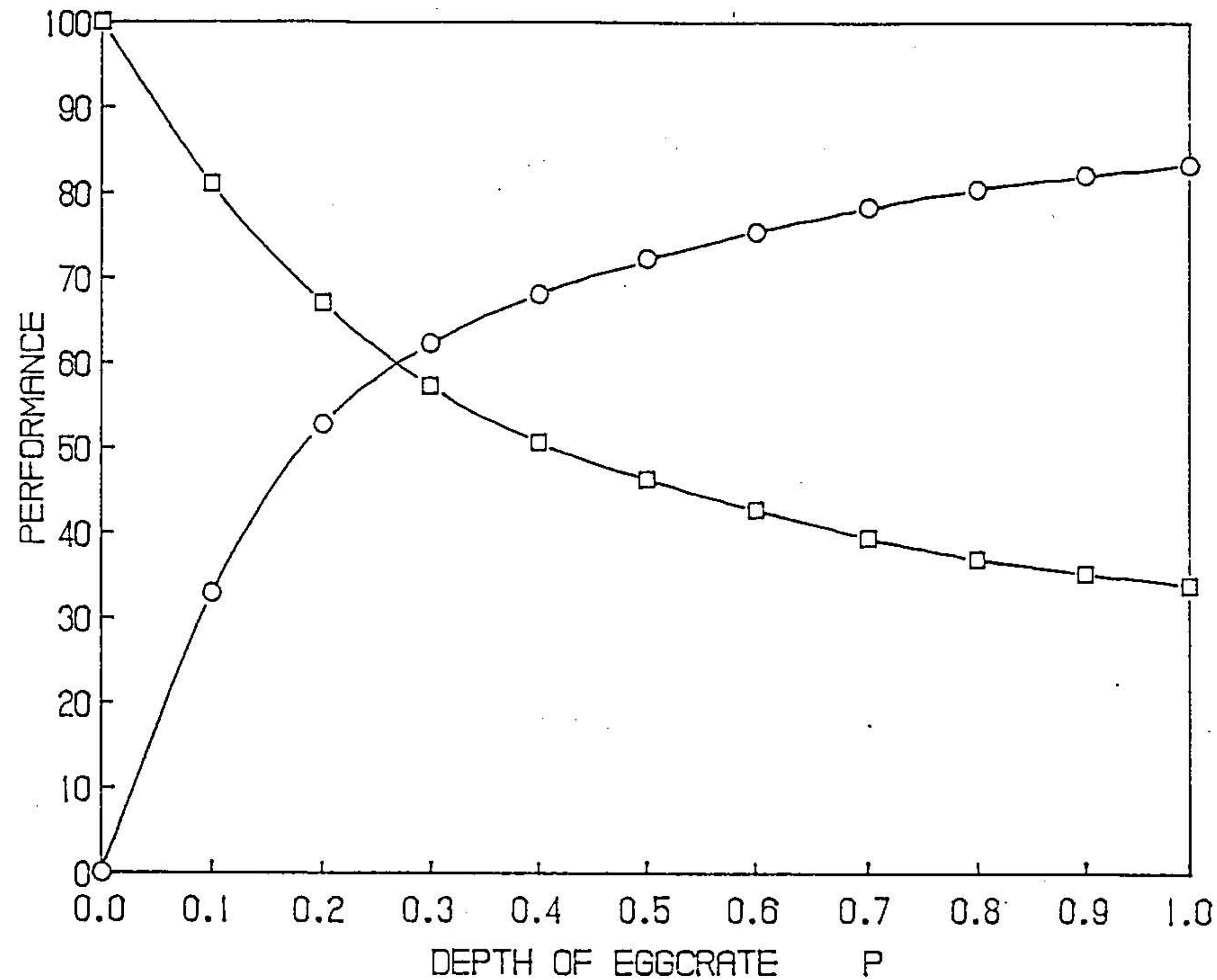


Fig (3.51)

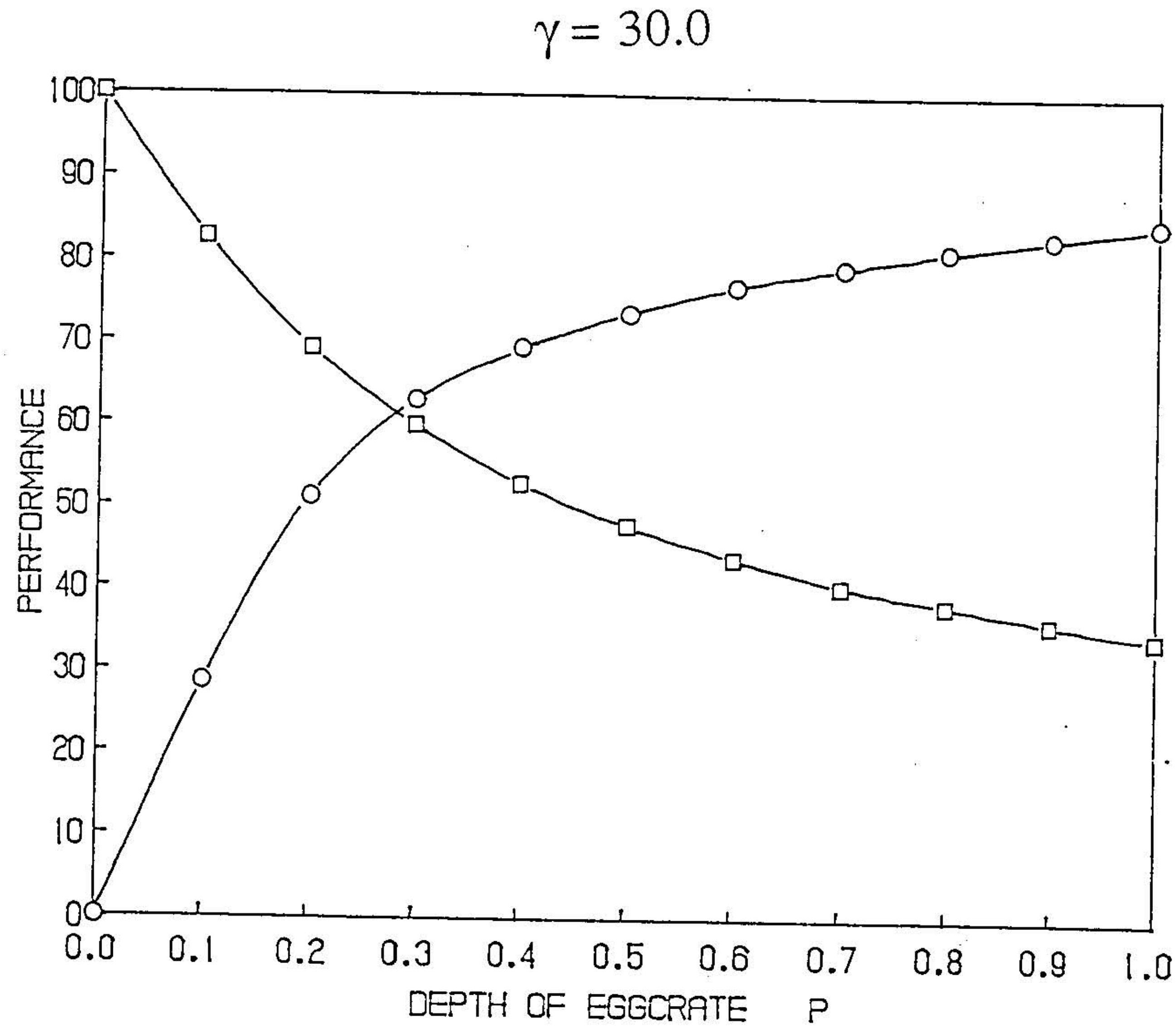

γ = 30.0
PERFORMANCE
0
10
20
30
40
50
60
70
80
90
100
0.0
0.1
0.2
0.3
0.4
0.5
0.6
0.7
0.8
0.9
1.0
DEPTH OF EGGCRATE P

Fig (3.52)

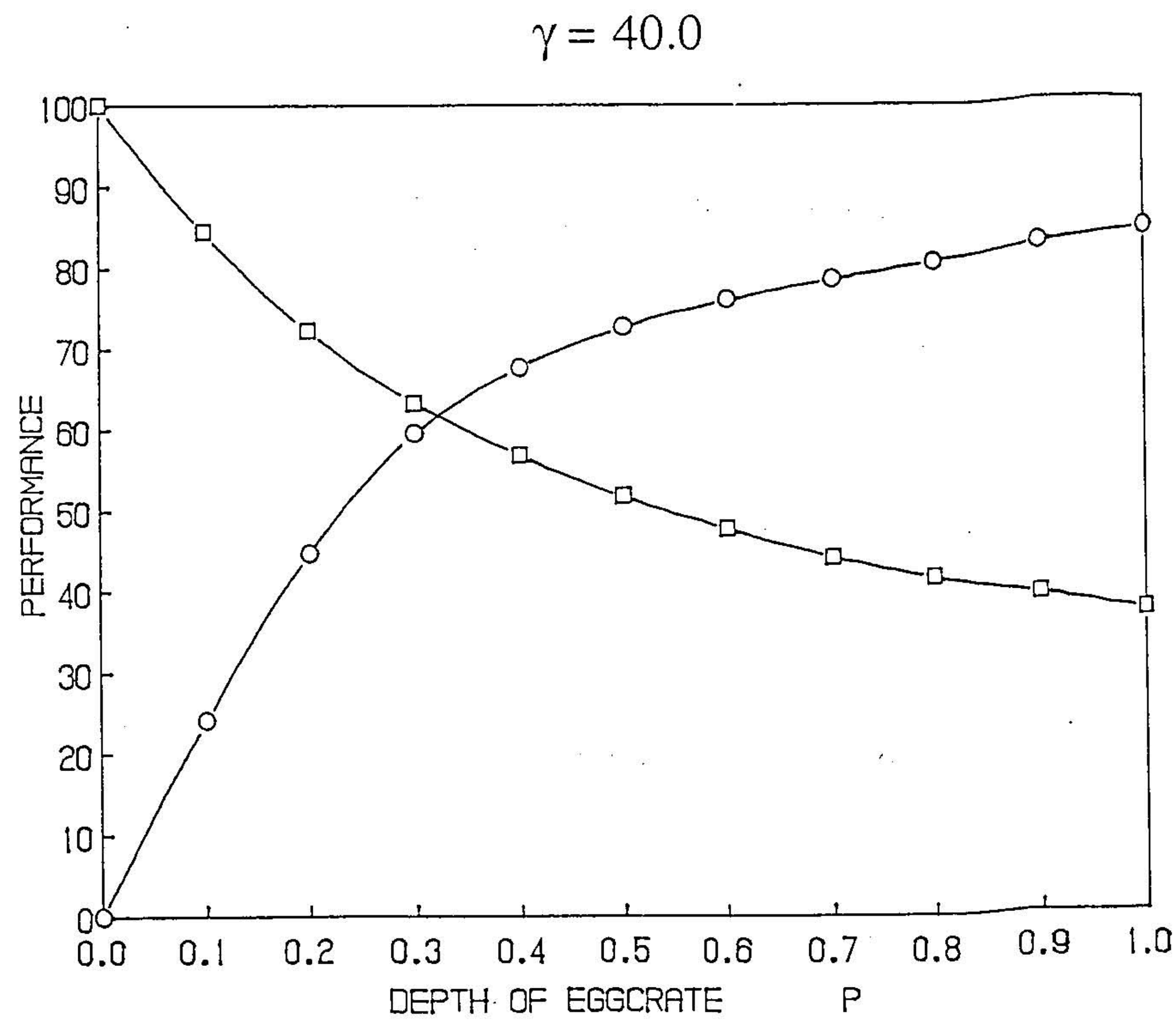

γ = 40.0
PERFORMANCE
100
90
80
70
60
50
40
30
20
10
0
0.0
0.1
0.2
0.3
0.4
0.5
0.6
0.7
0.8
0.9
1.0
DEPTH OF EGGCRATE P

Fig (3.53)

$\gamma = 50.0$

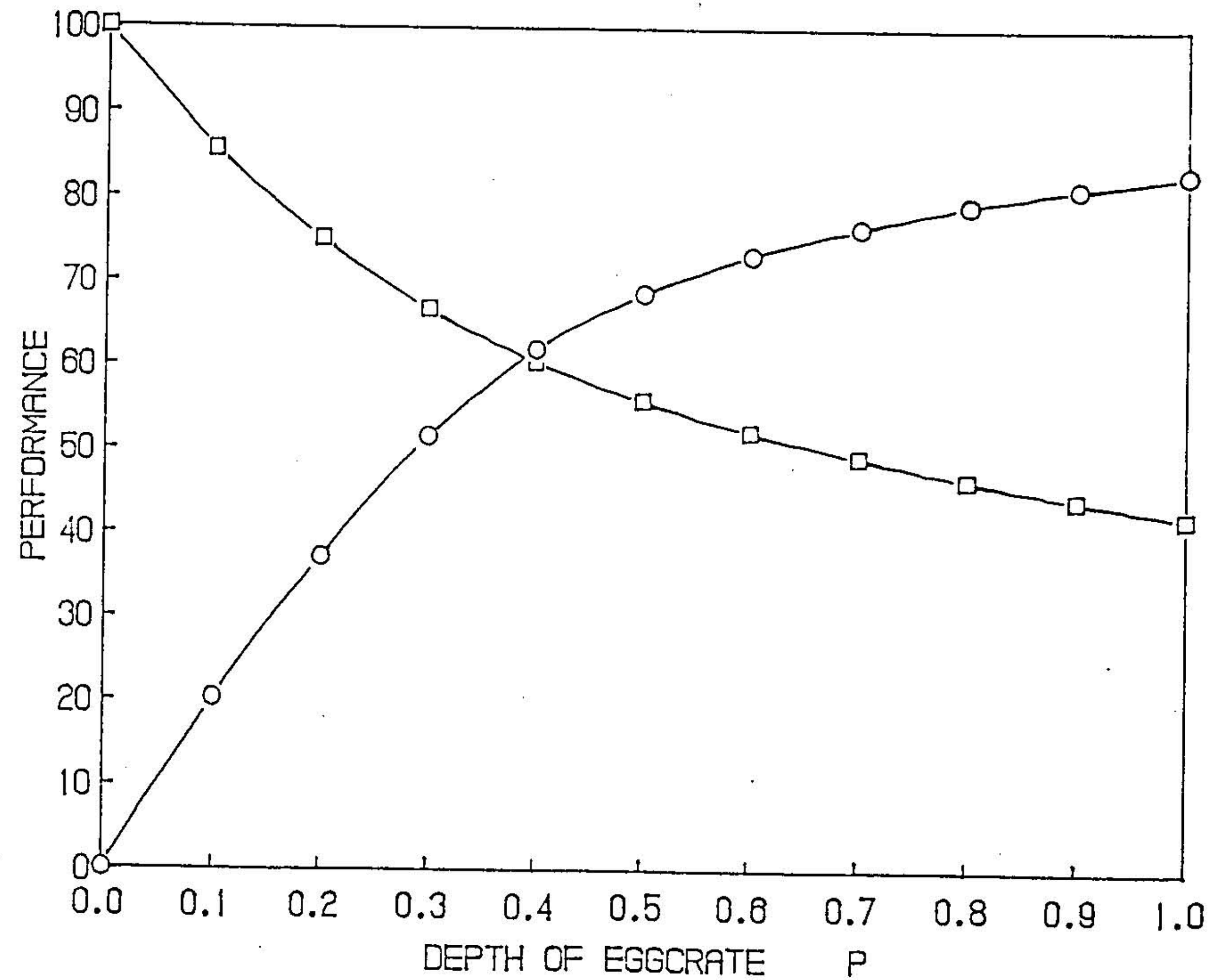


Fig (3.54)

$\gamma = 60.0$

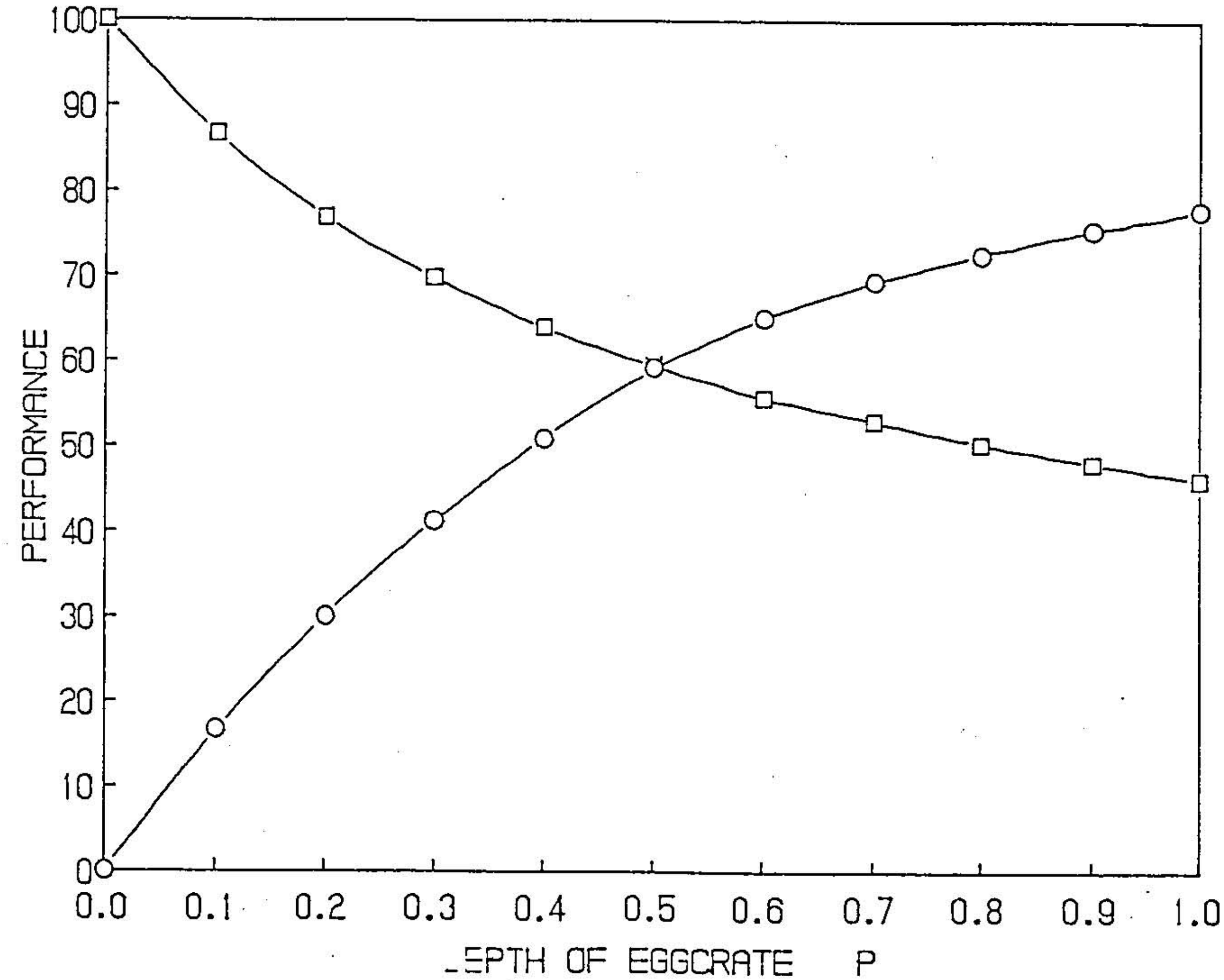


Fig (3.55)

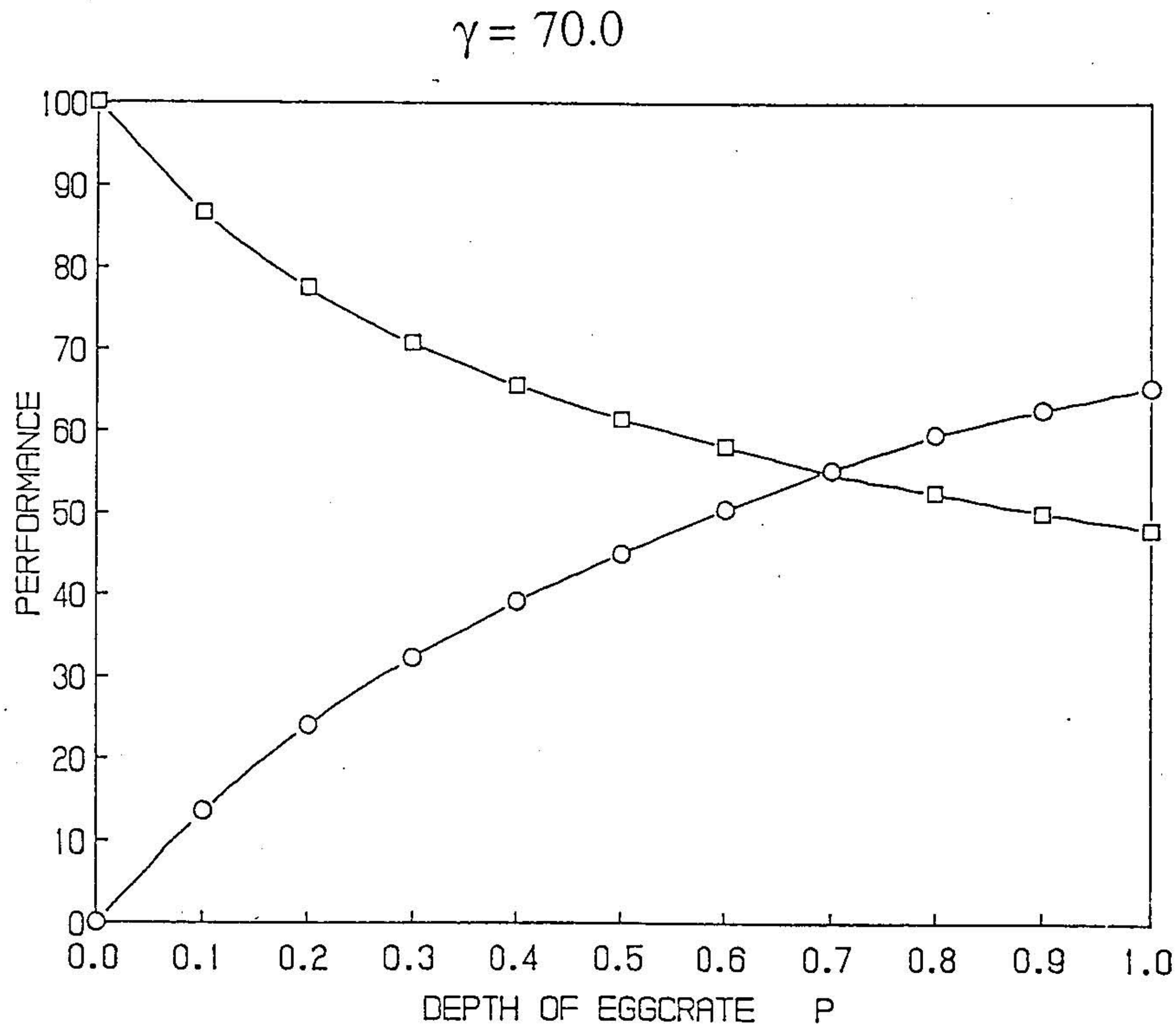

γ = 70.0
PERFORMANCE
0
10
20
30
40
50
60
70
80
90
100
0.0
0.1
0.2
0.3
0.4
0.5
0.6
0.7
0.8
0.9
1.0
DEPTH OF EGGCRATE P

Fig (3.56)

$\gamma = 80.0$

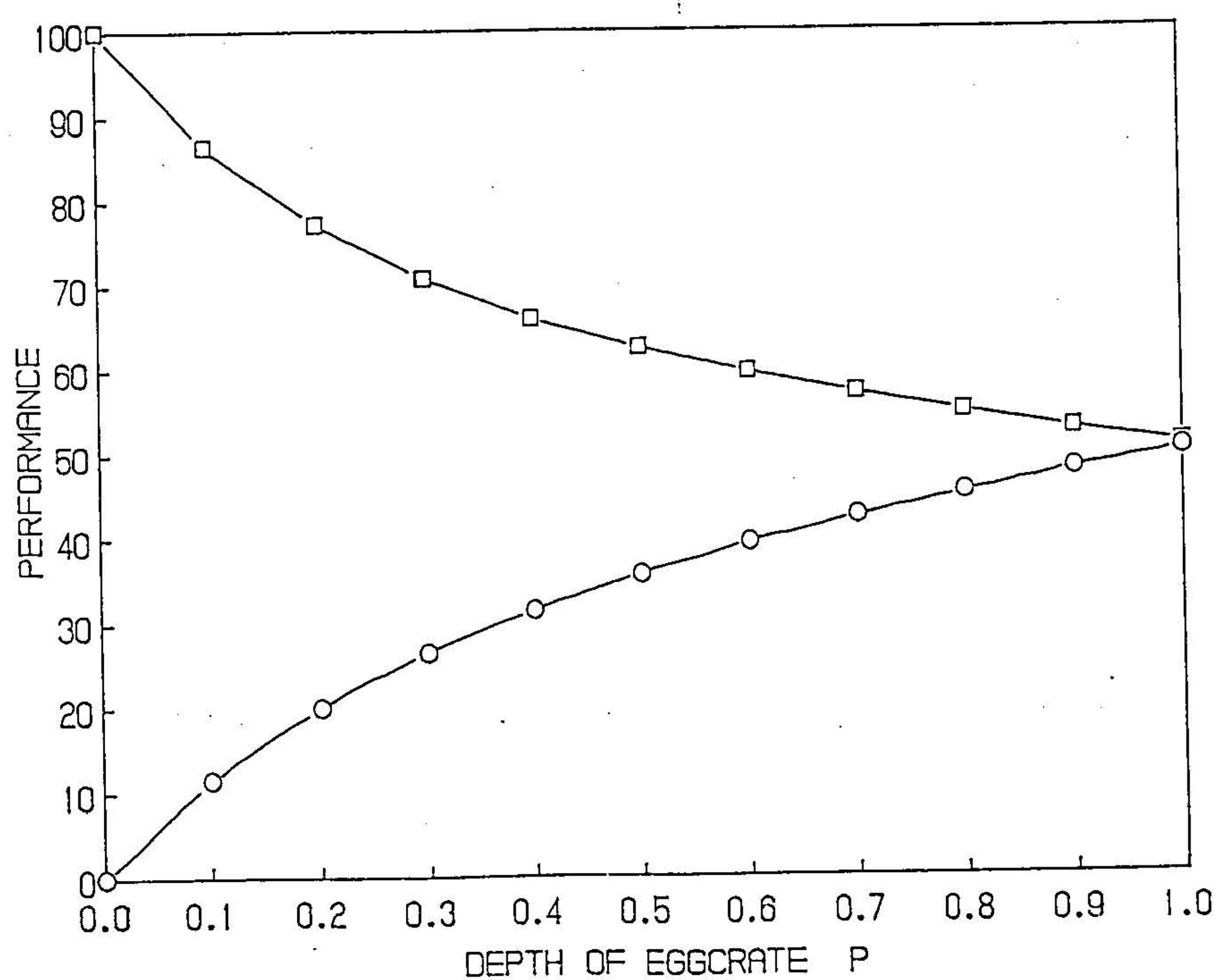


Fig (3.57)

$\gamma = 90.0$

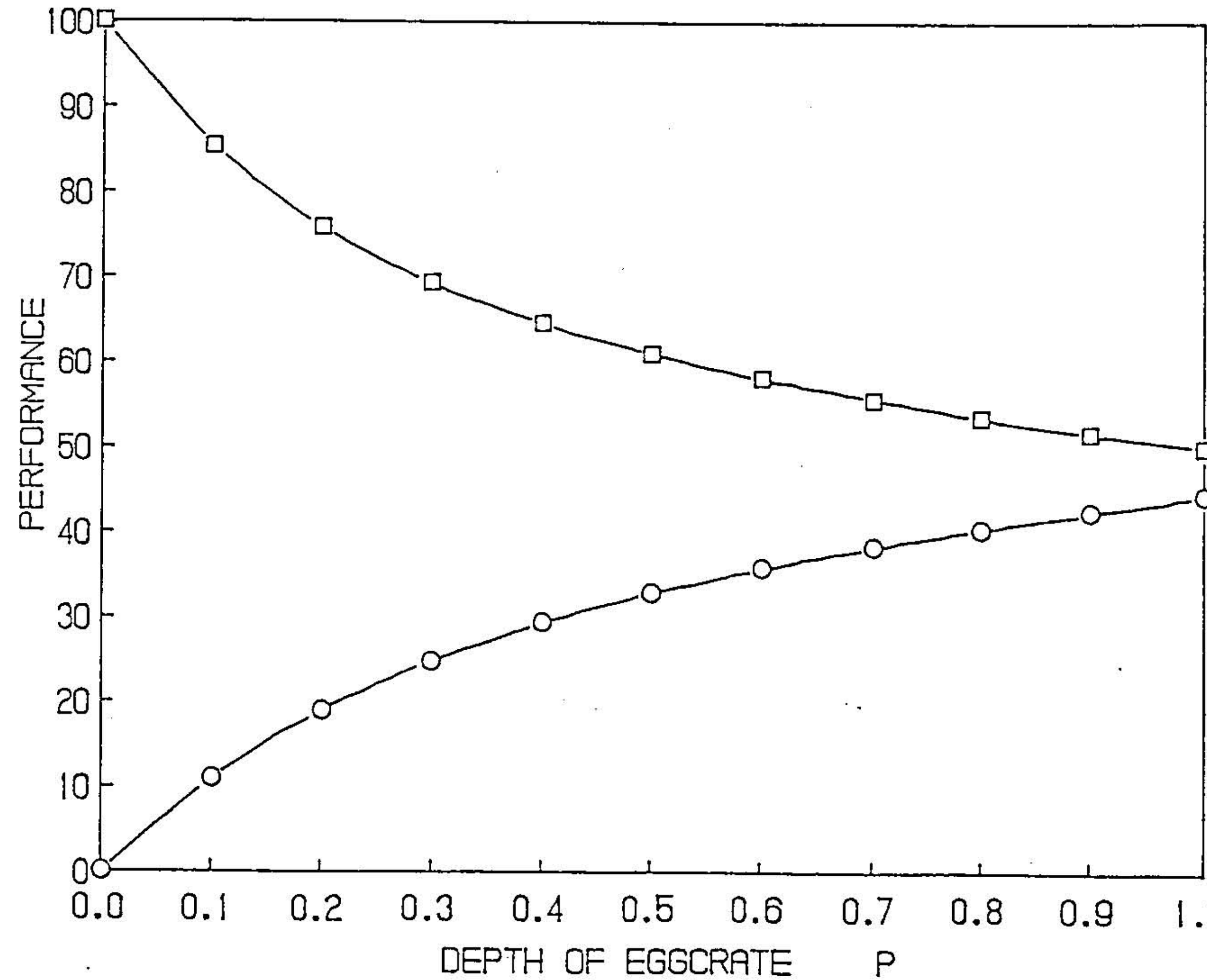


Fig (3.58)

$\gamma = 100.0$

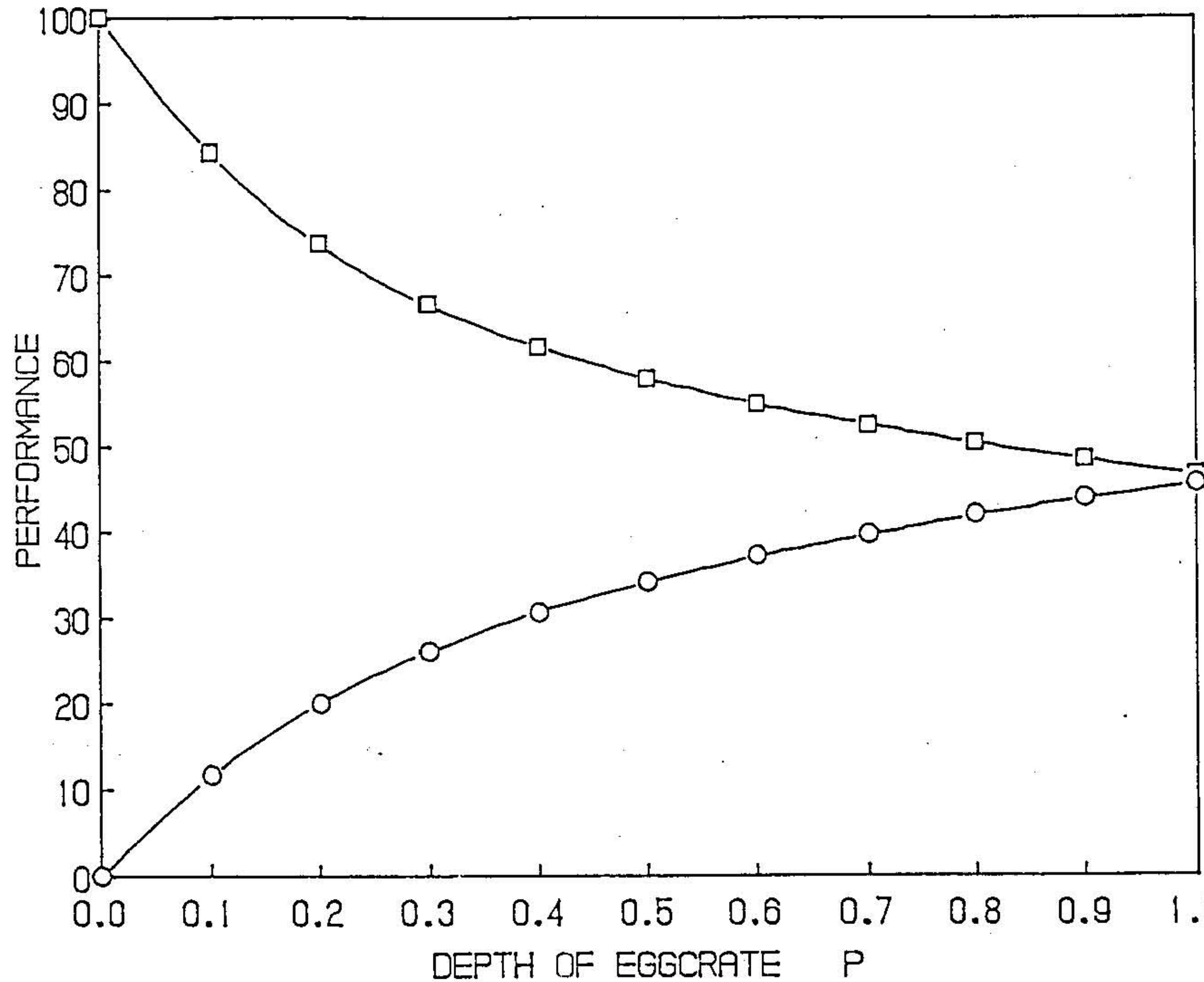


Fig (3.59)

$\gamma = 110.0$

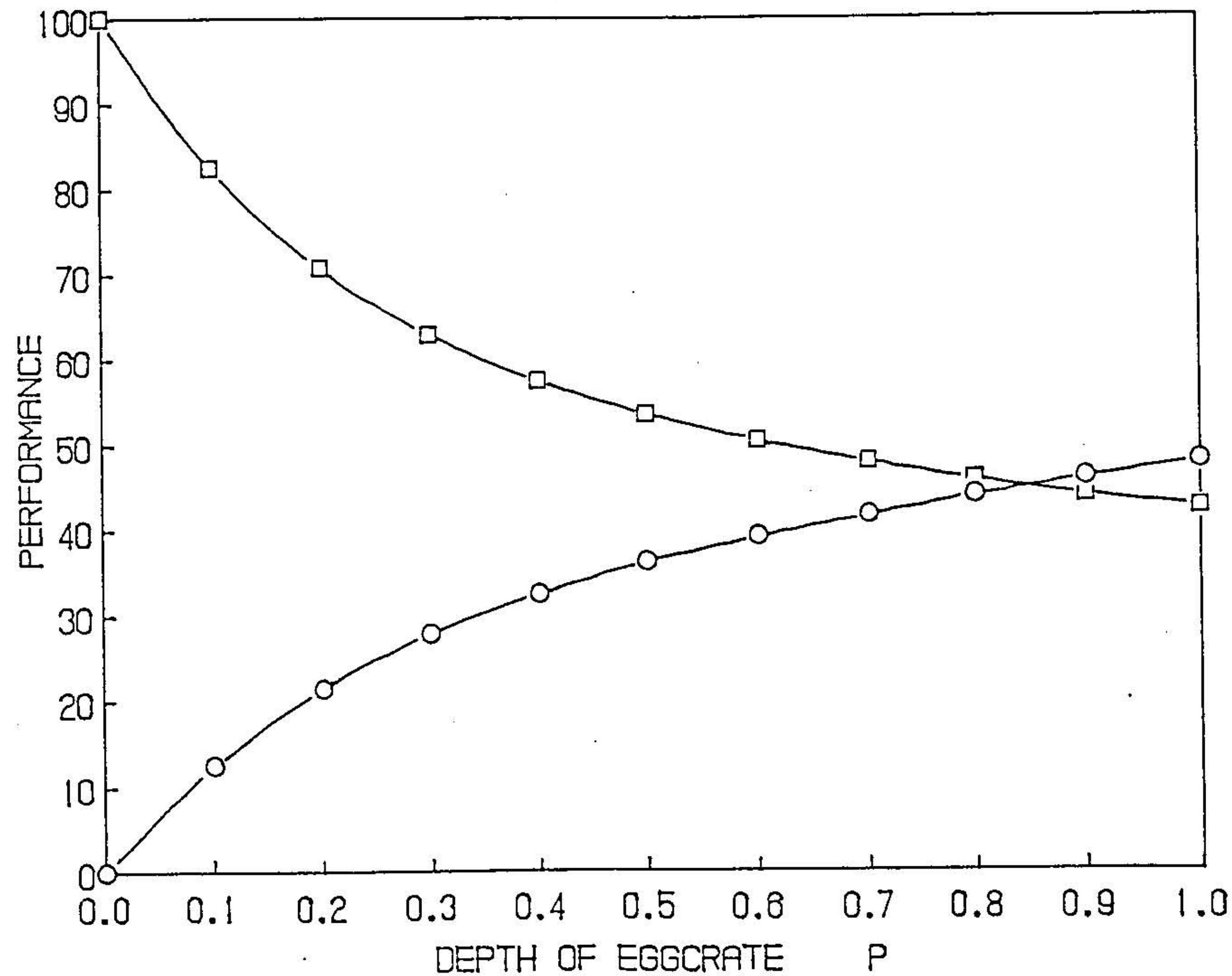


Fig (3.60)

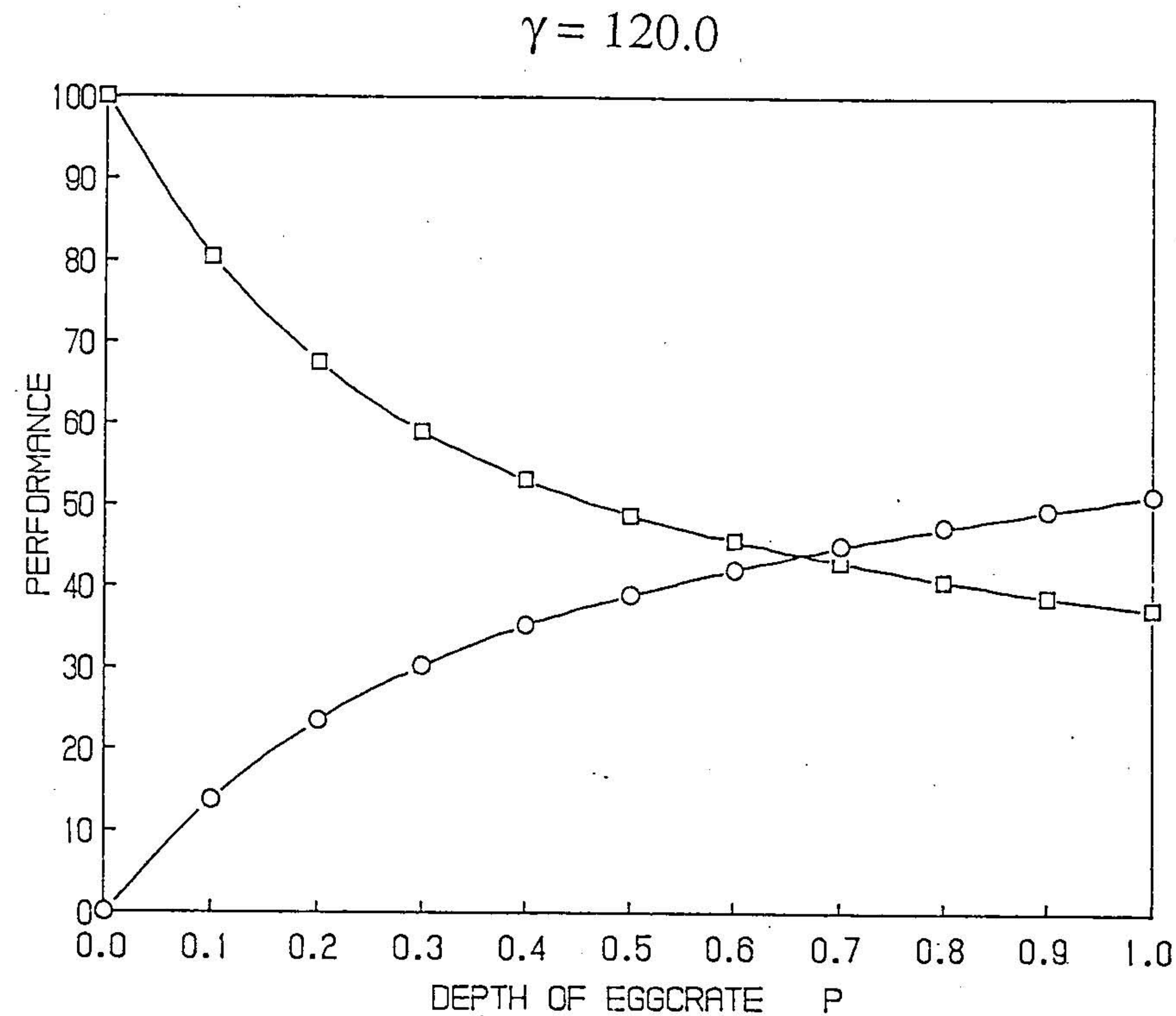

γ = 120.0
100
90
80
70
60
50
40
30
20
10
0
PERFORMANCE
0.0
0.1
0.2
0.3
0.4
0.5
0.6
0.7
0:8
0.9
1.0
DEPTH OF EGGCRATE P

Fig (3.61)

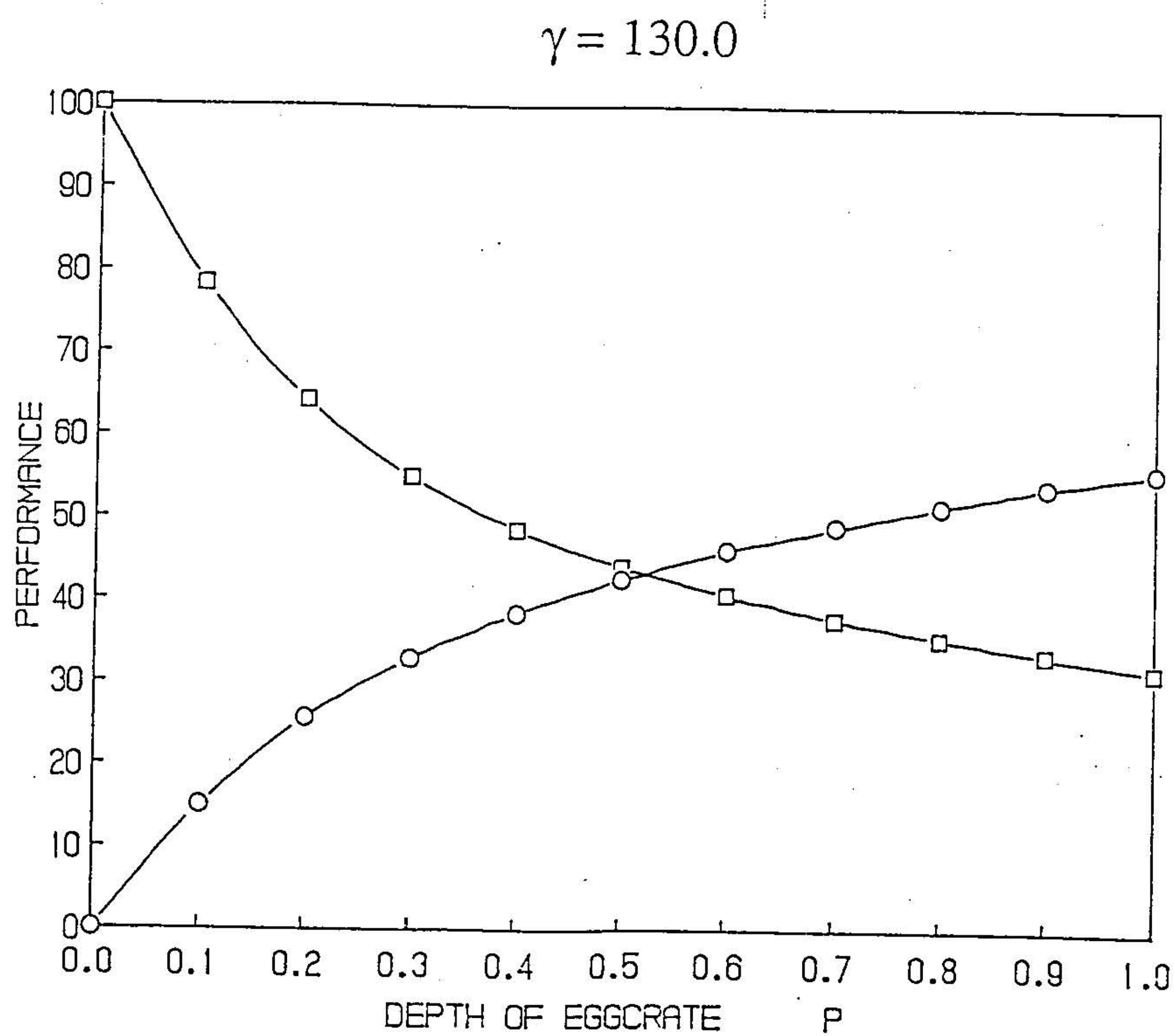

γ = 130.0
PERFORMANCE
0
10
20
30
40
50
60
70
80
90
100
0.0
0.1
0.2
0.3
0.4
0.5
0.6
0.7
0.8
0.9
1.0
DEPTH OF EGGCRATE P

Fig (3.62)

$\gamma = 140.0$

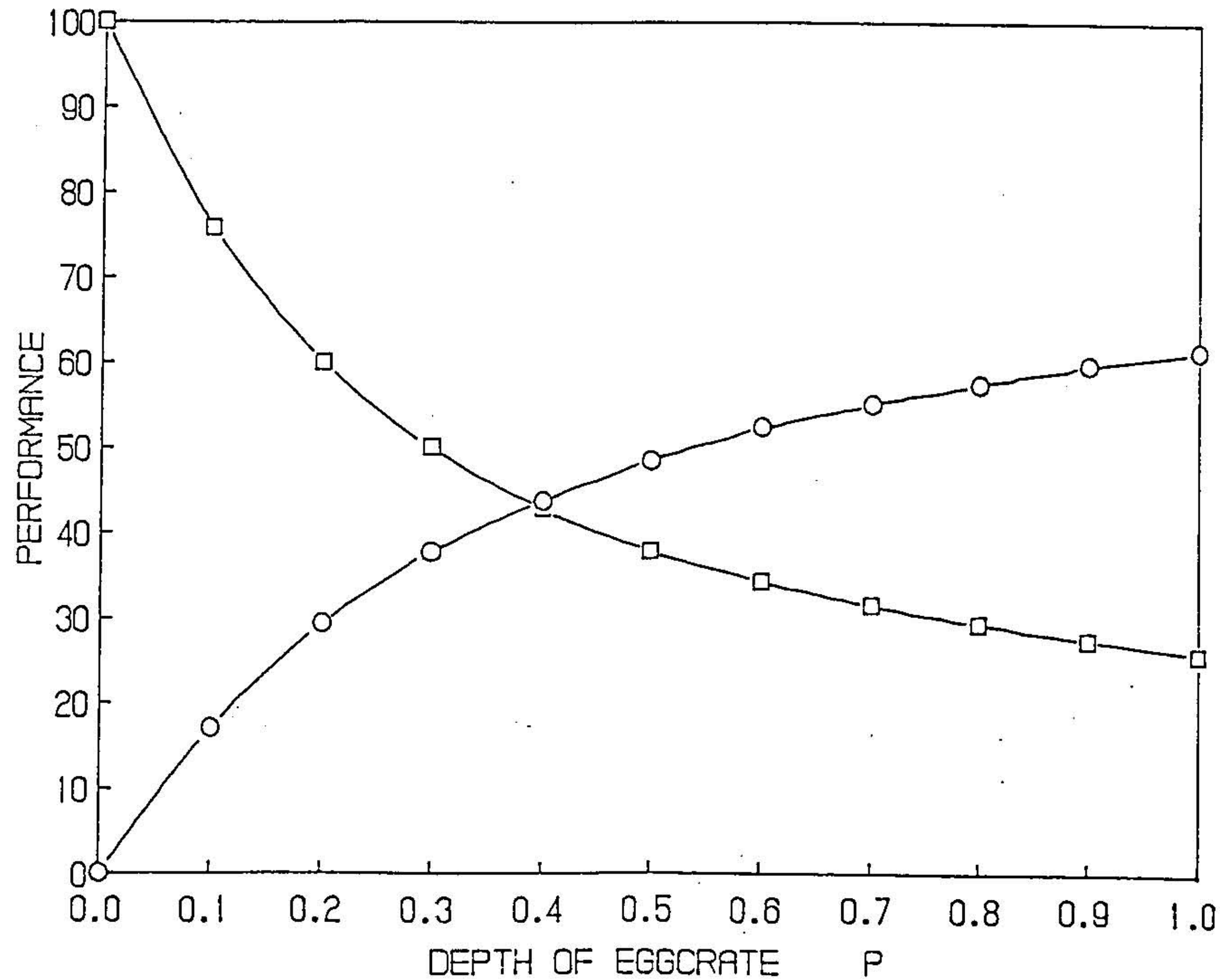


Fig (3.63)

$\gamma = 150.0$

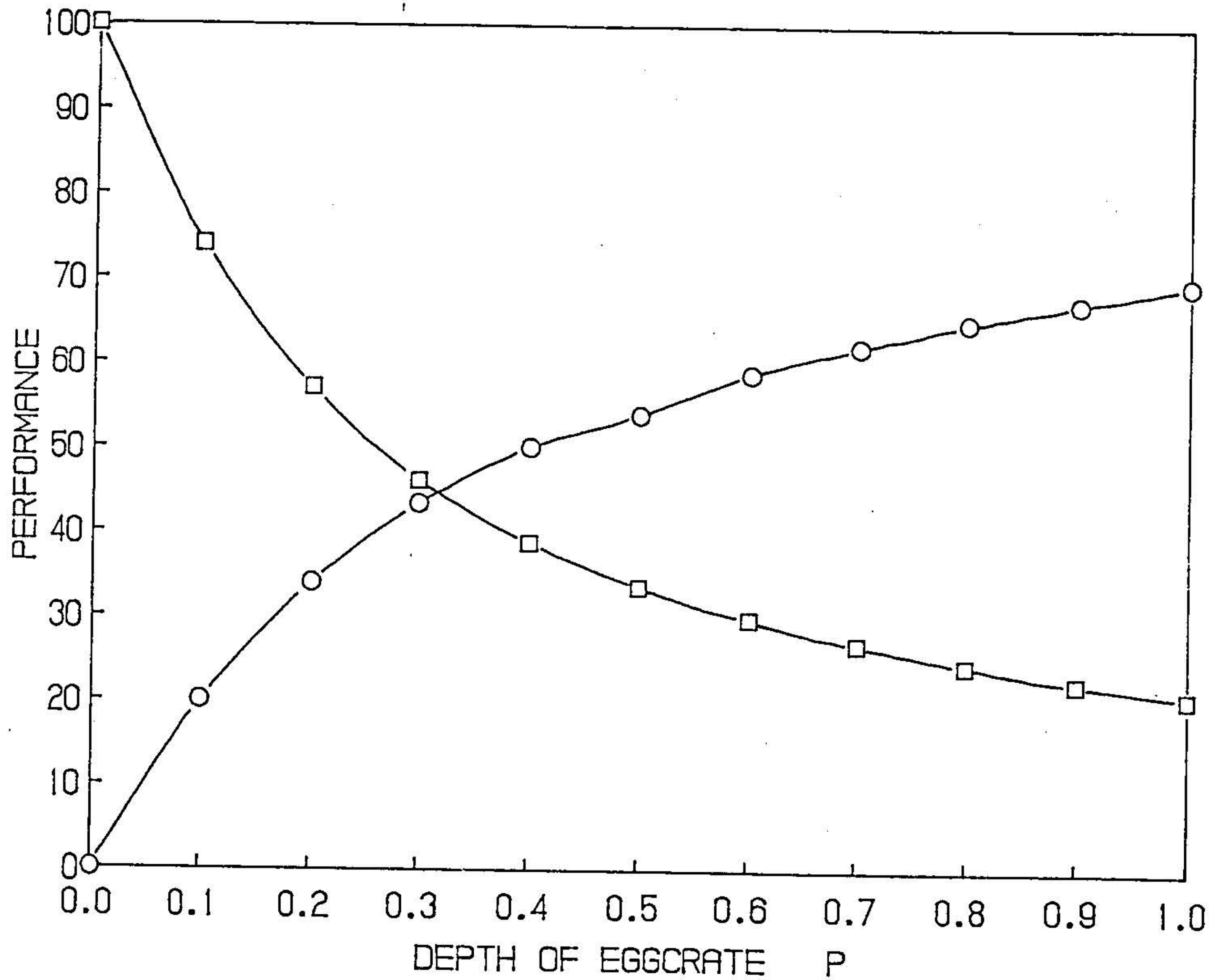


Fig (3.64)

$\gamma = 160.0$

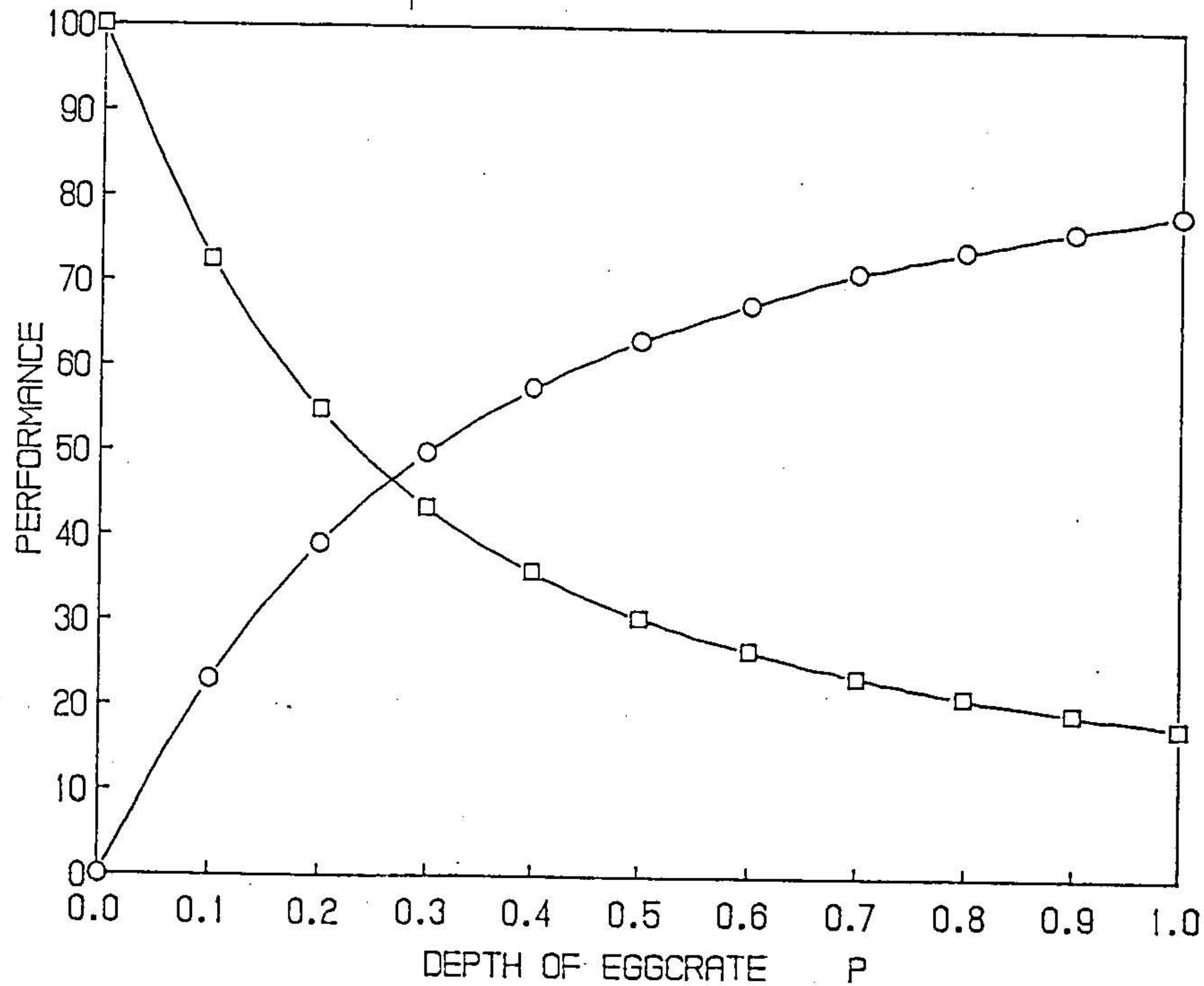


Fig (3.65)

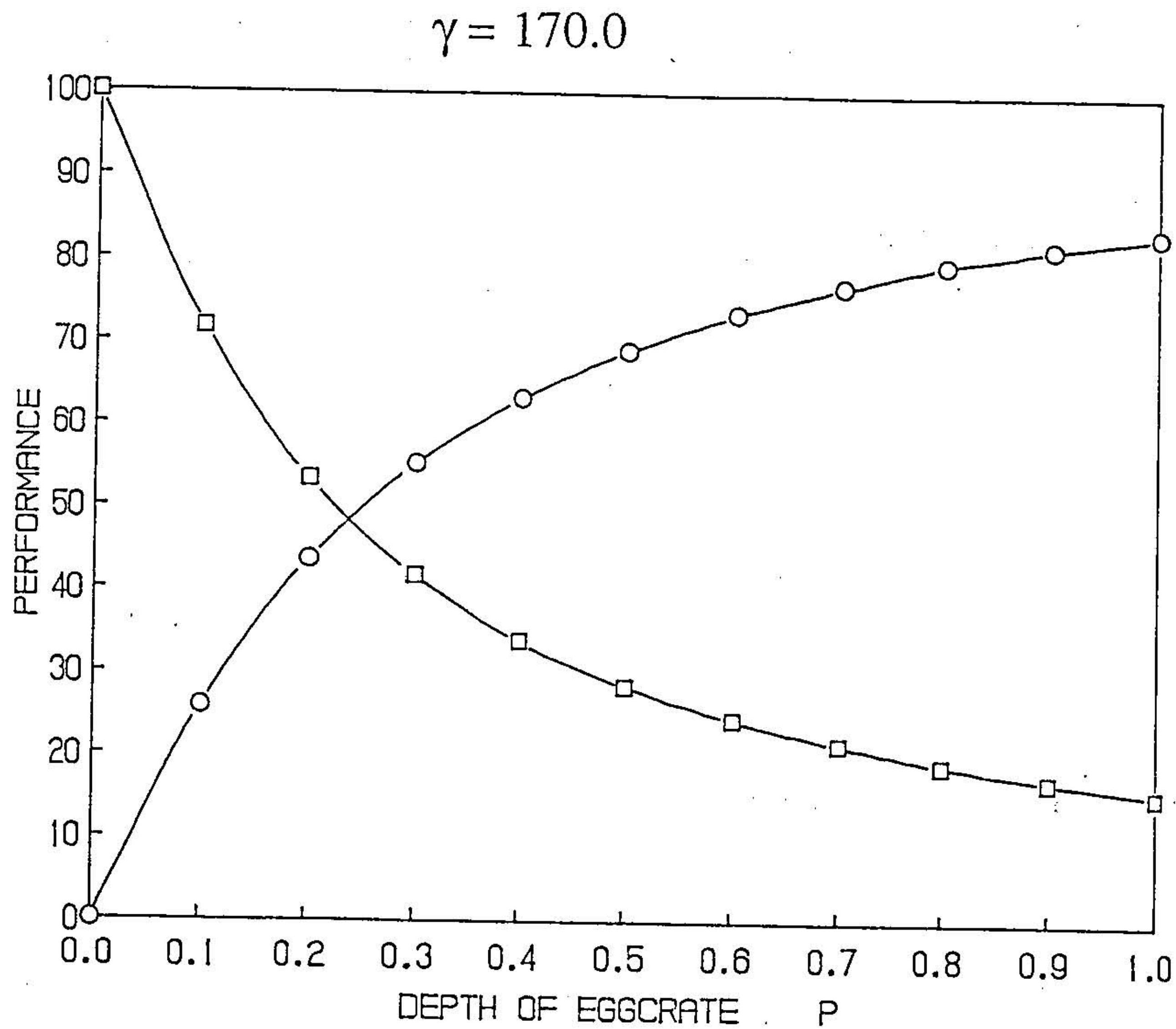

γ = 170.0
PERFORMANCE
100
90
80
70
60
50
40
30
20
10
0
0.0
0.1
0.2
0.3
0.4
0.5
0.6
0.7
0.8
0.9
1.0
DEPTH OF EGGCRATE P

Fig (3.66)

$\gamma = 180.0$

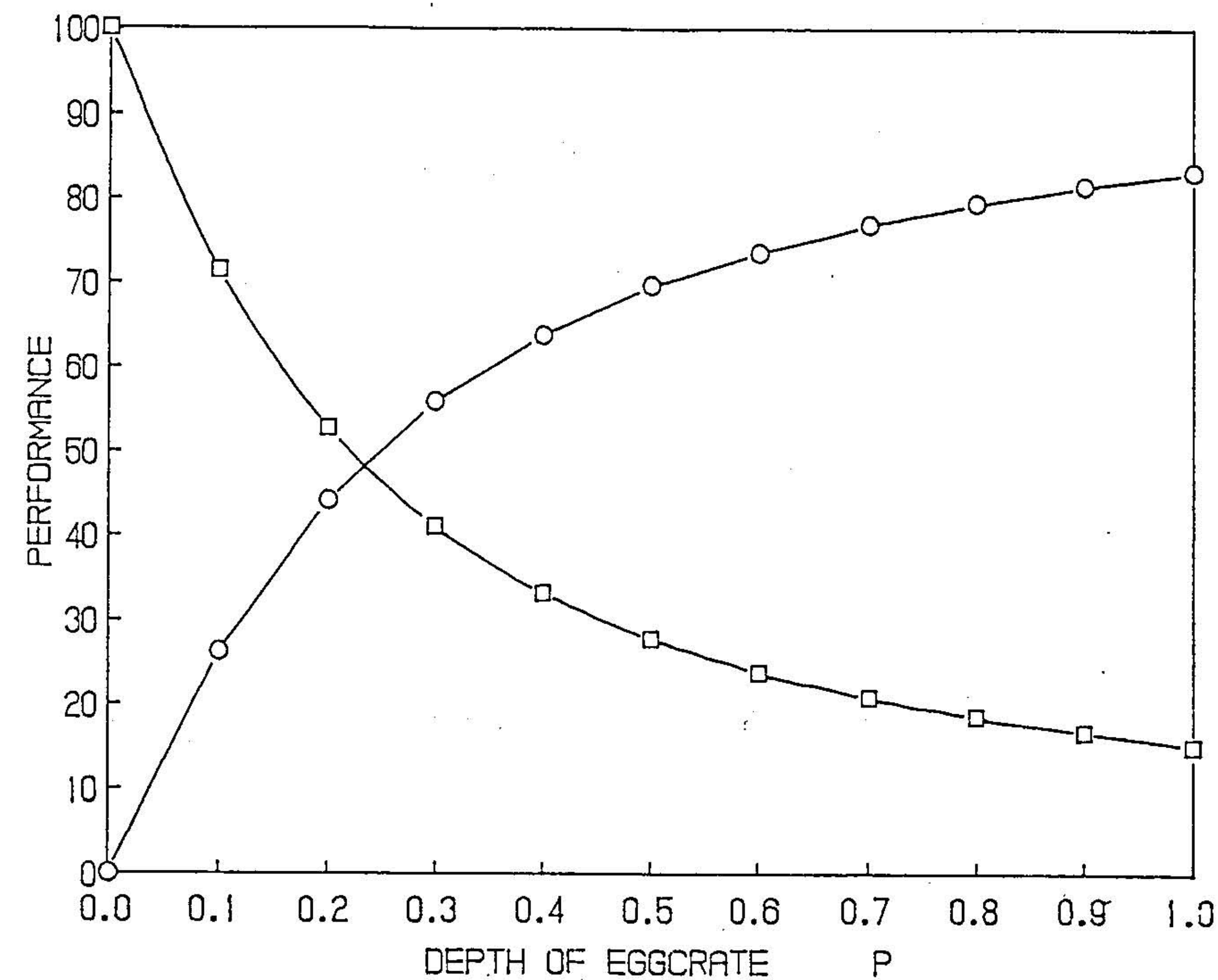


Fig (3.67)

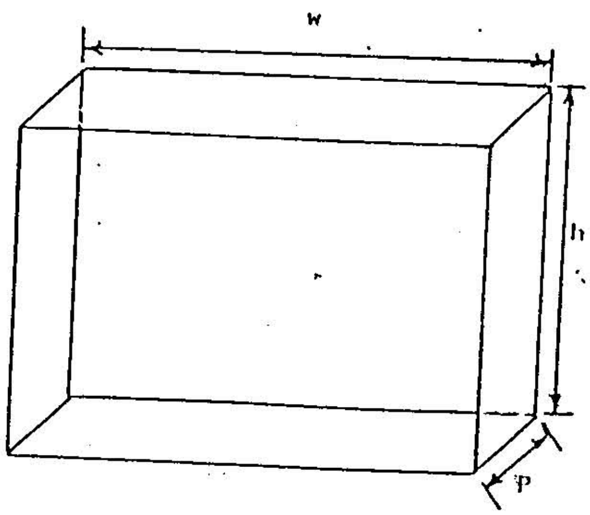
Summer and winter performances
curves for horizontal eggcrate
shading window devices in Jordan

Fig (3.68) - Fig (3.86)

H = relative height = 4.0
W = relative width = 0.25

—— □ —— summer performances

—— * —— winter performances .



$\gamma = 10.0$

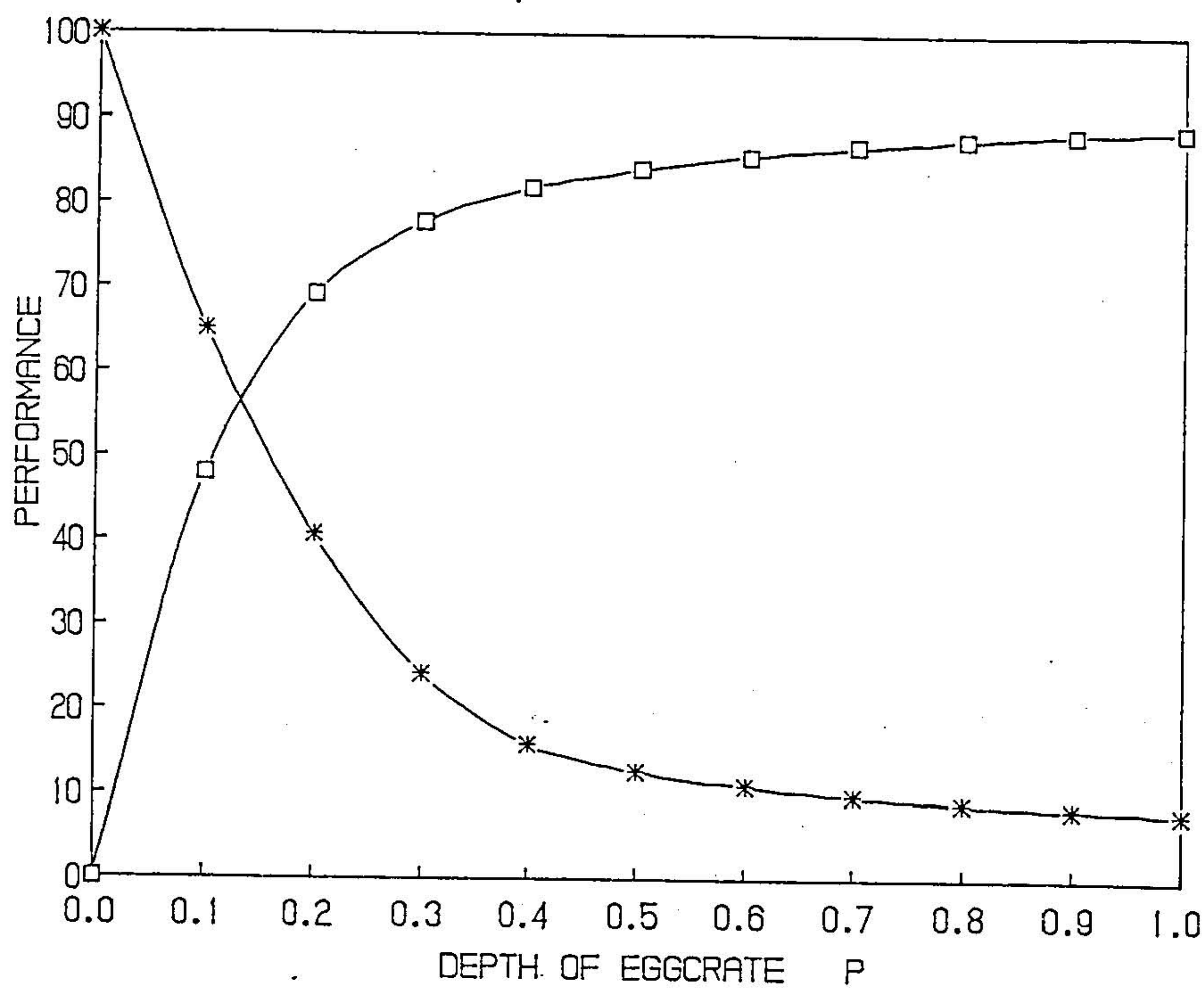


Fig (3.69)

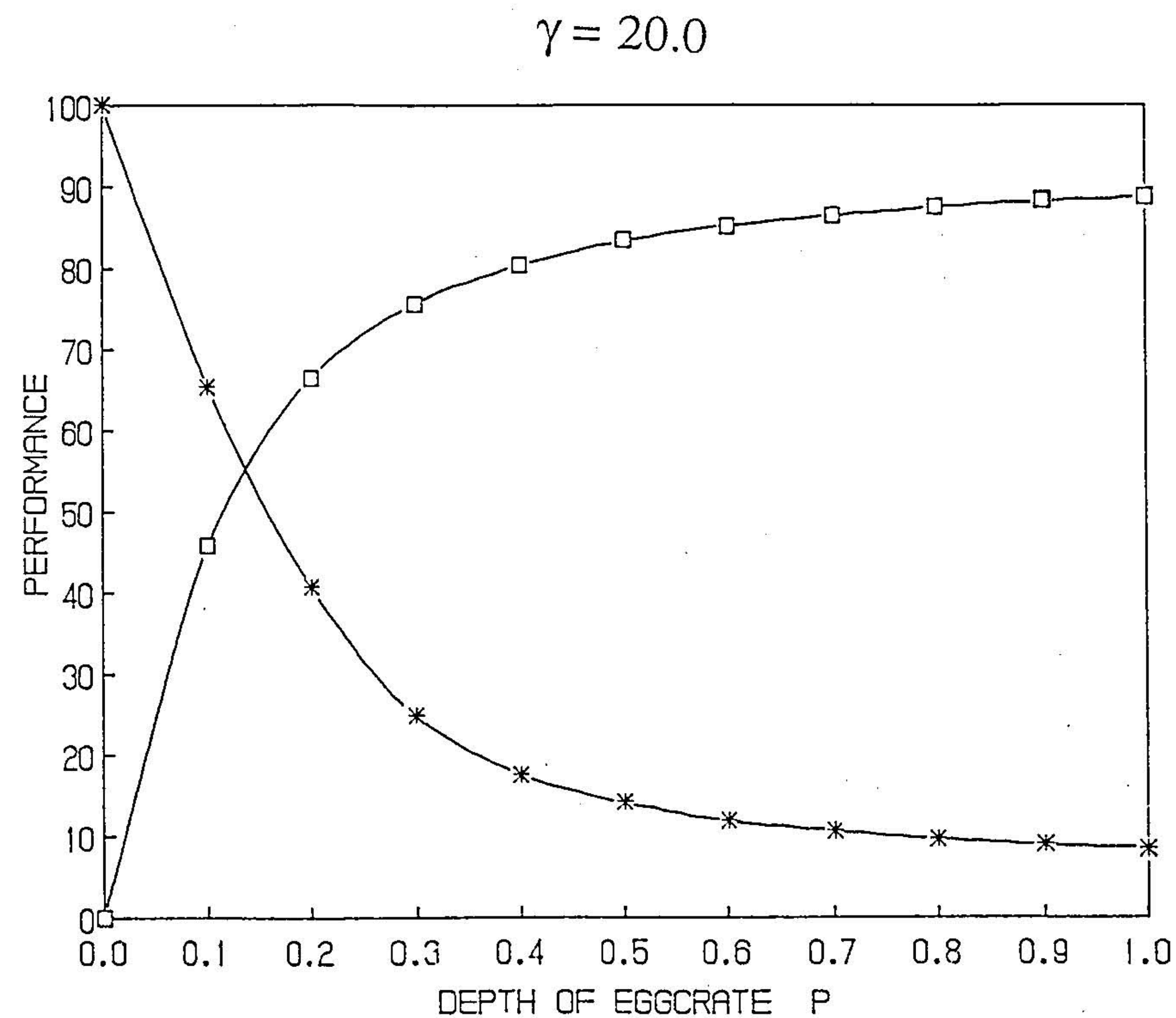

γ = 20.0
PERFORMANCE
100
90
80
70
60
50
40
30
20
10
0
0.0
0.1
0.2
0.3
0.4
0.5
0.6
0.7
0.8
0.9
1.0
DEPTH OF EGGCRATE P

Fig (3.70)

$\gamma = 30.0$

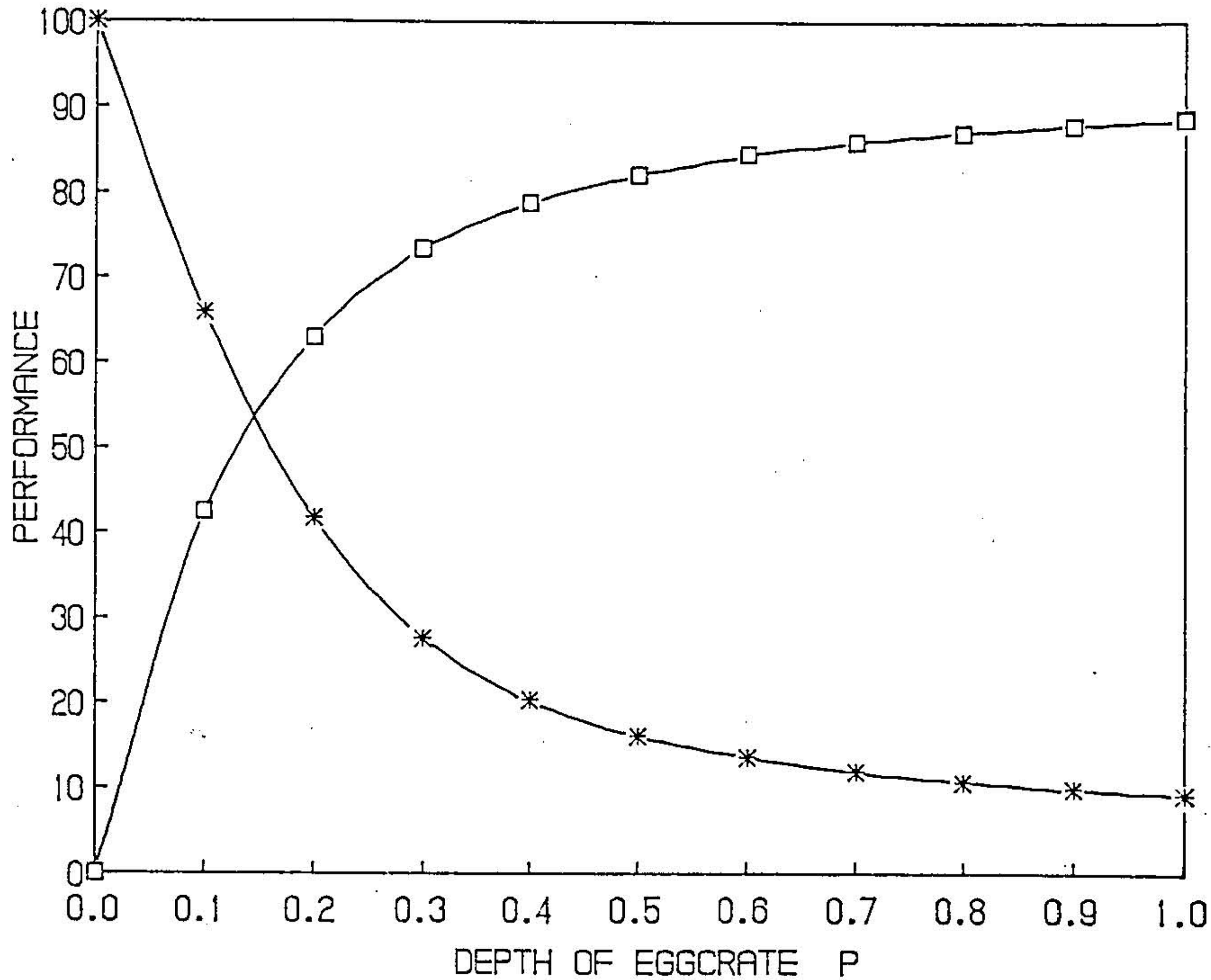


Fig (3.71)

$\gamma = 40.0$

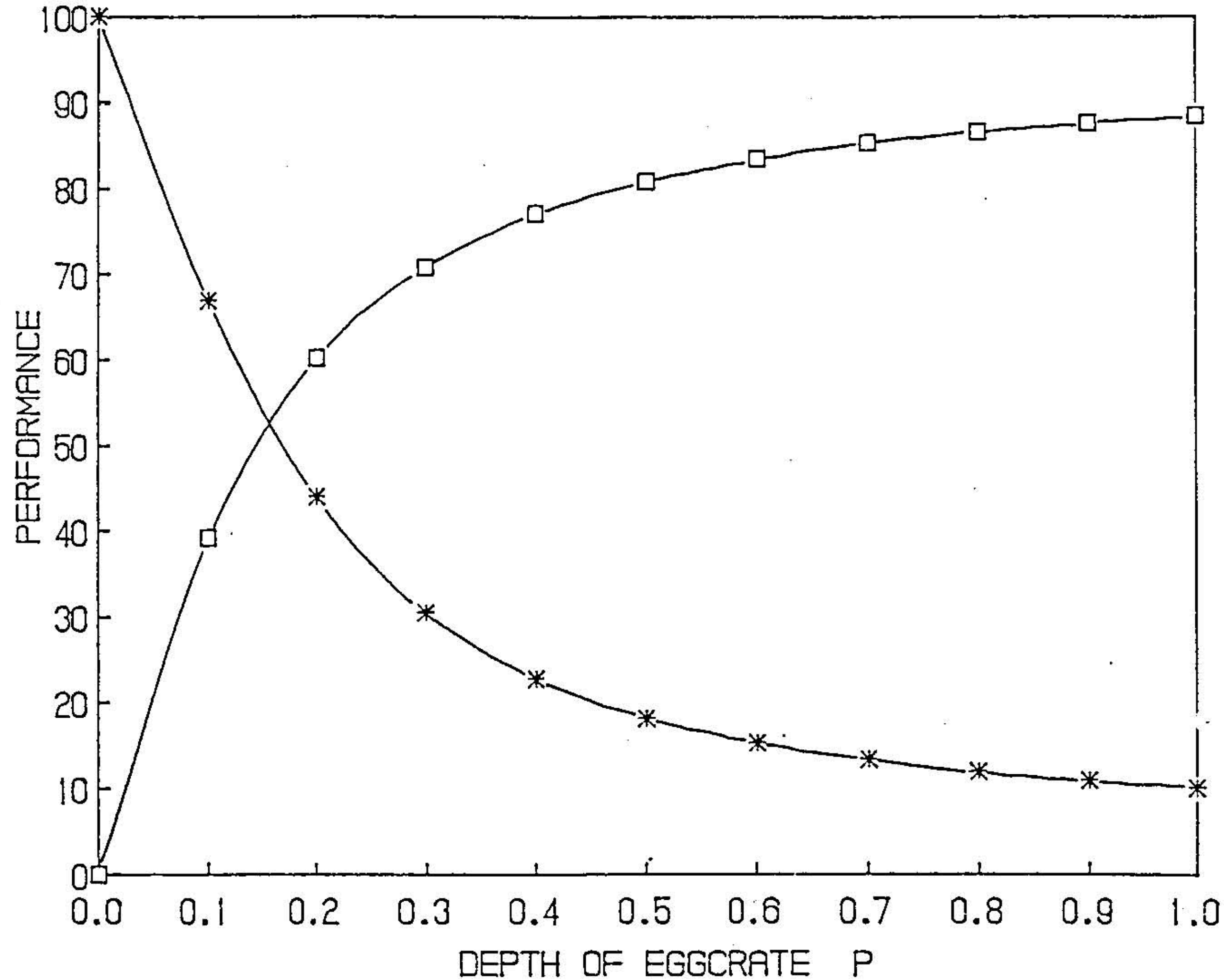


Fig (3.72)

$\gamma = 50.0$

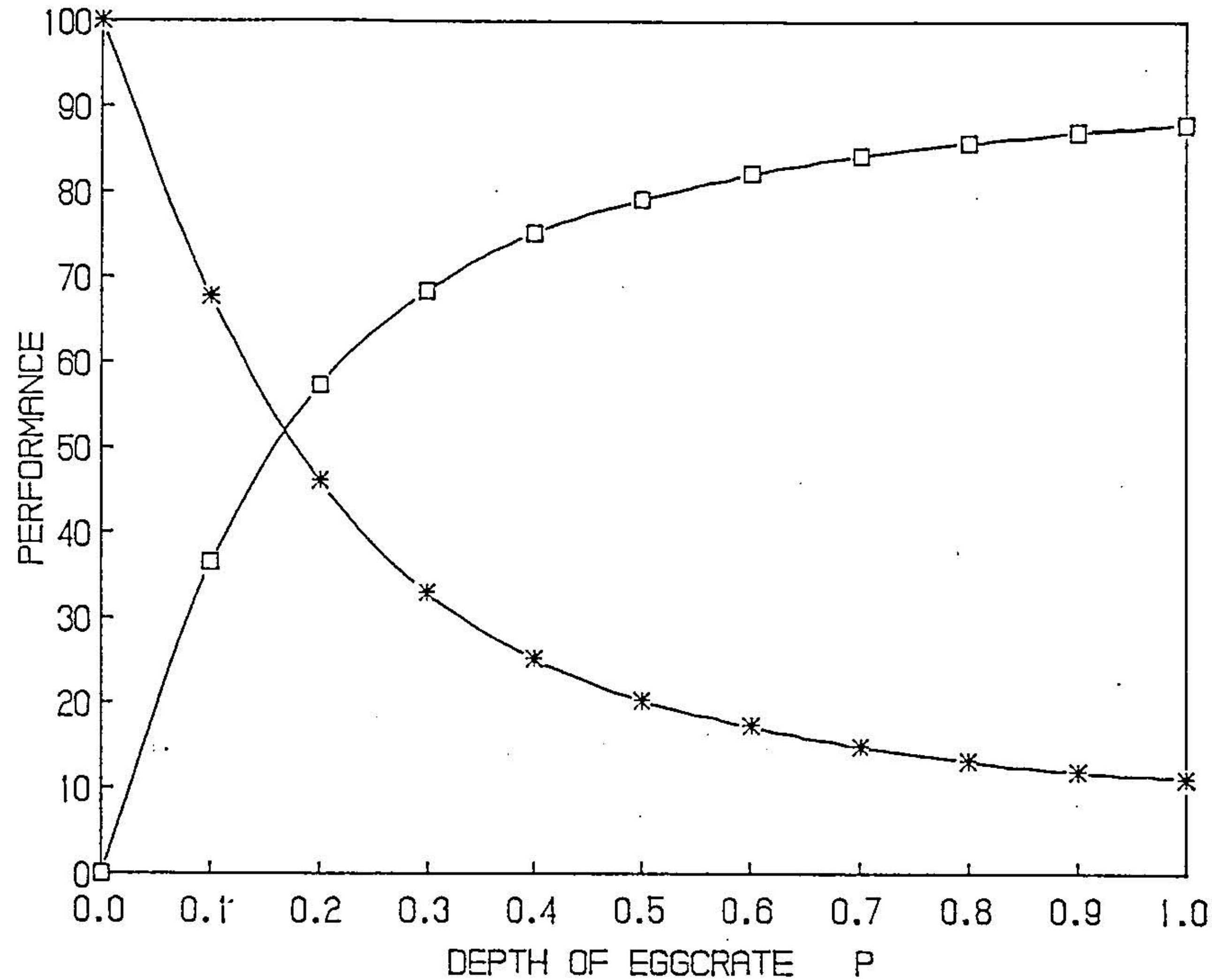


Fig (3.73)

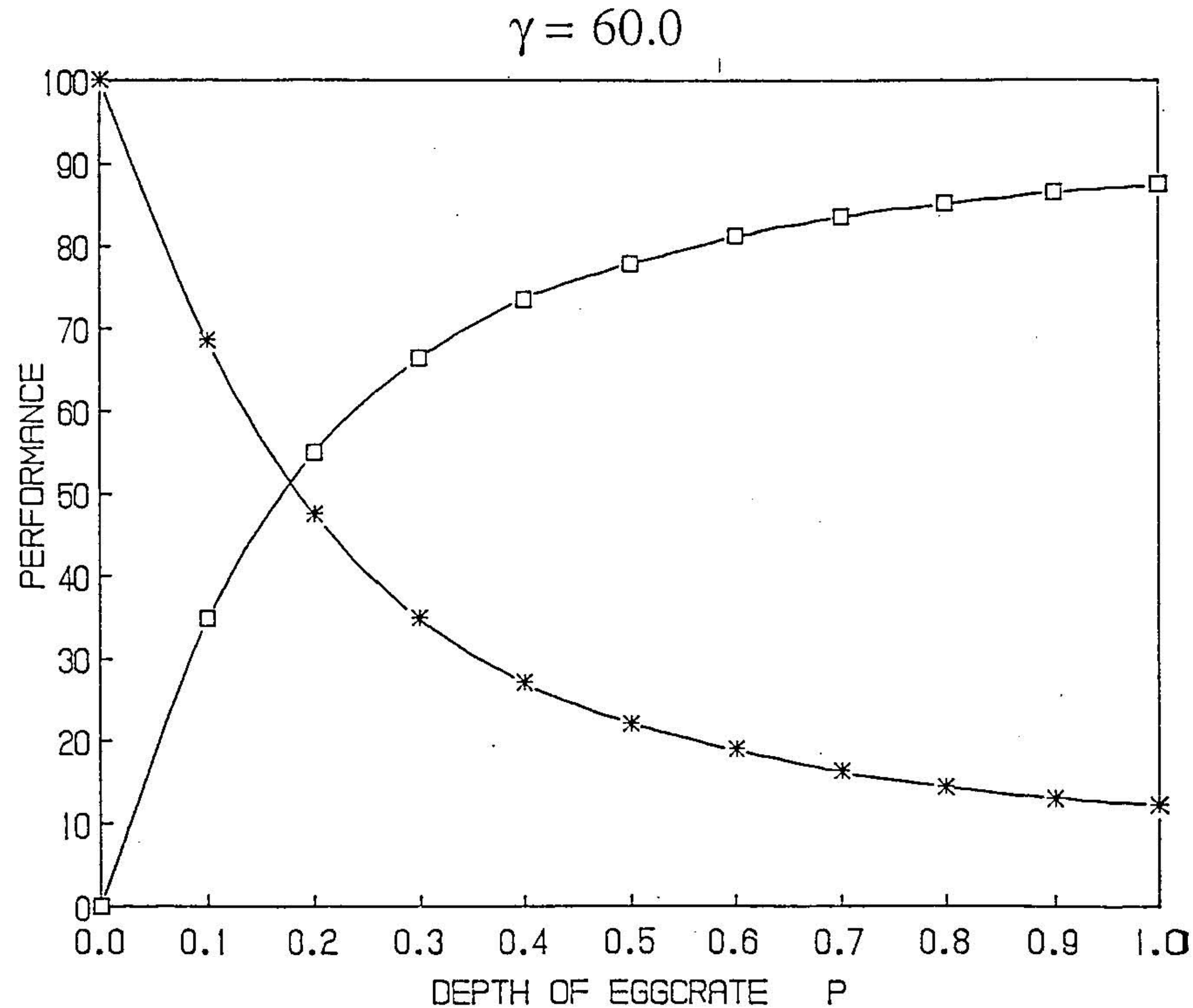

γ = 60.0
PERFORMANCE
100
90
80
70
60
50
40
30
20
10
0
0.0
0.1
0.2
0.3
0.4
0.5
0.6
0.7
0.8
0.9
1.0
DEPTH OF EGGCRATE P

Fig (3.74)

$\gamma = 70.0$

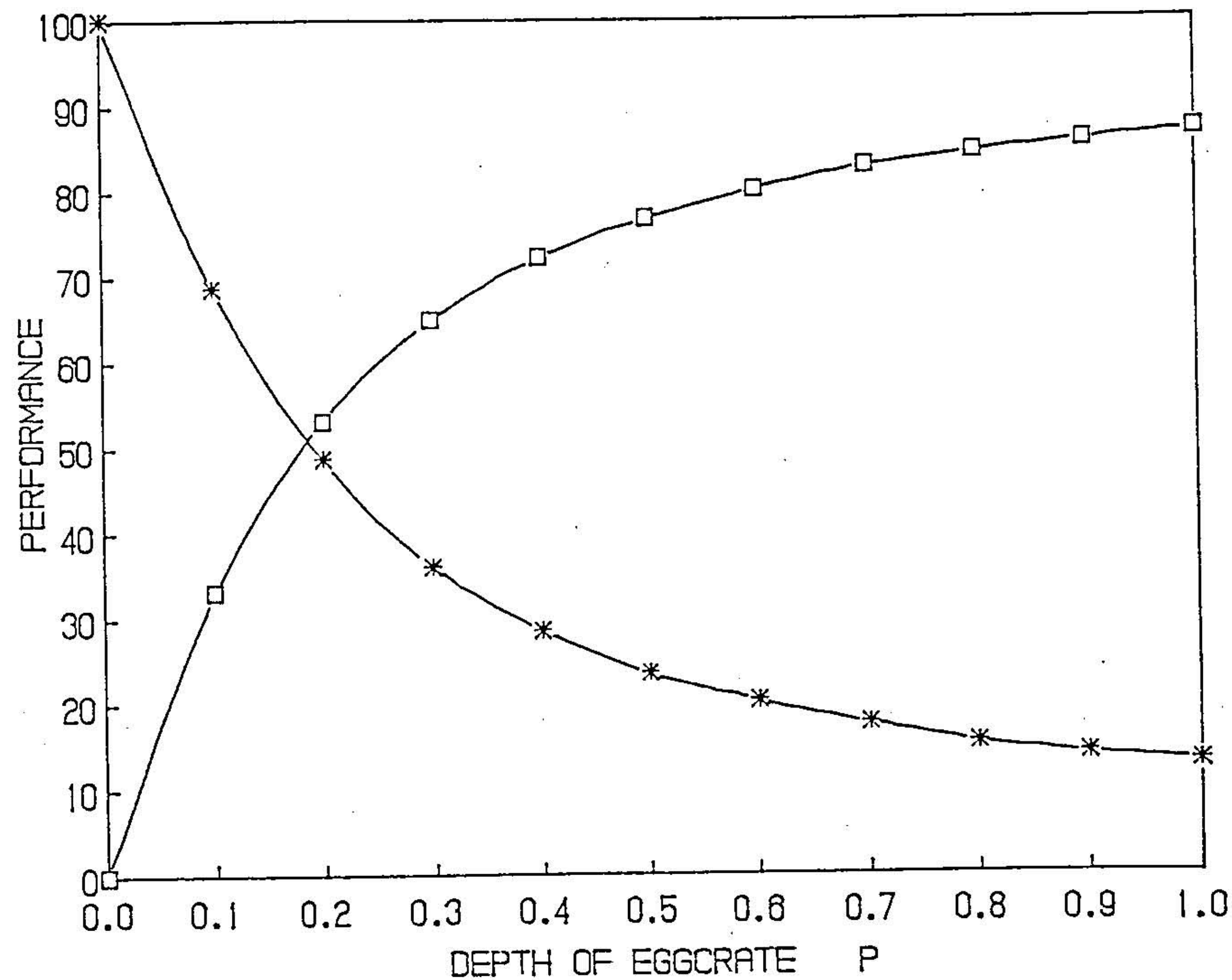


Fig (3.75)

$\gamma = 80.0$

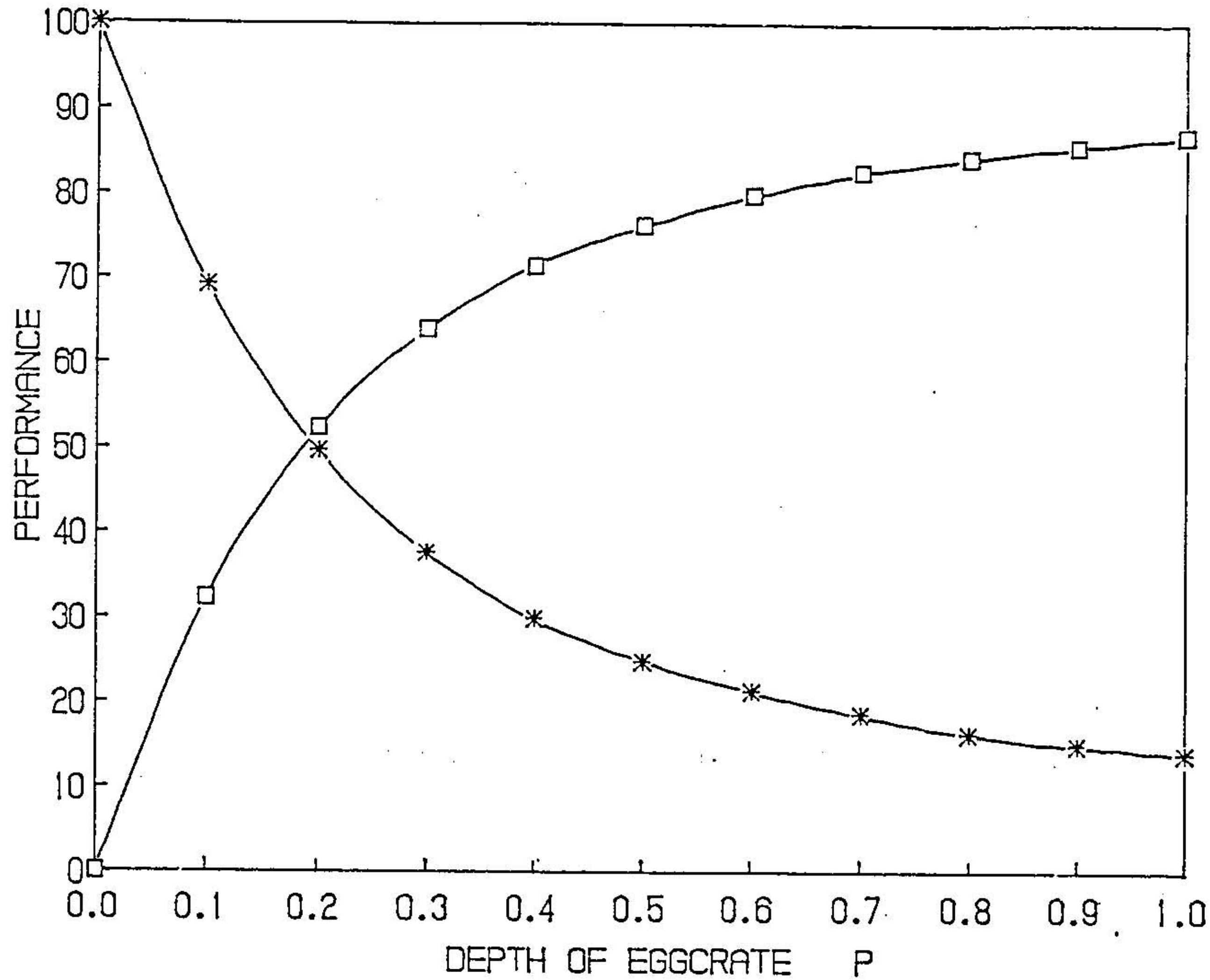


Fig (3.76)

$\gamma = 90.0$

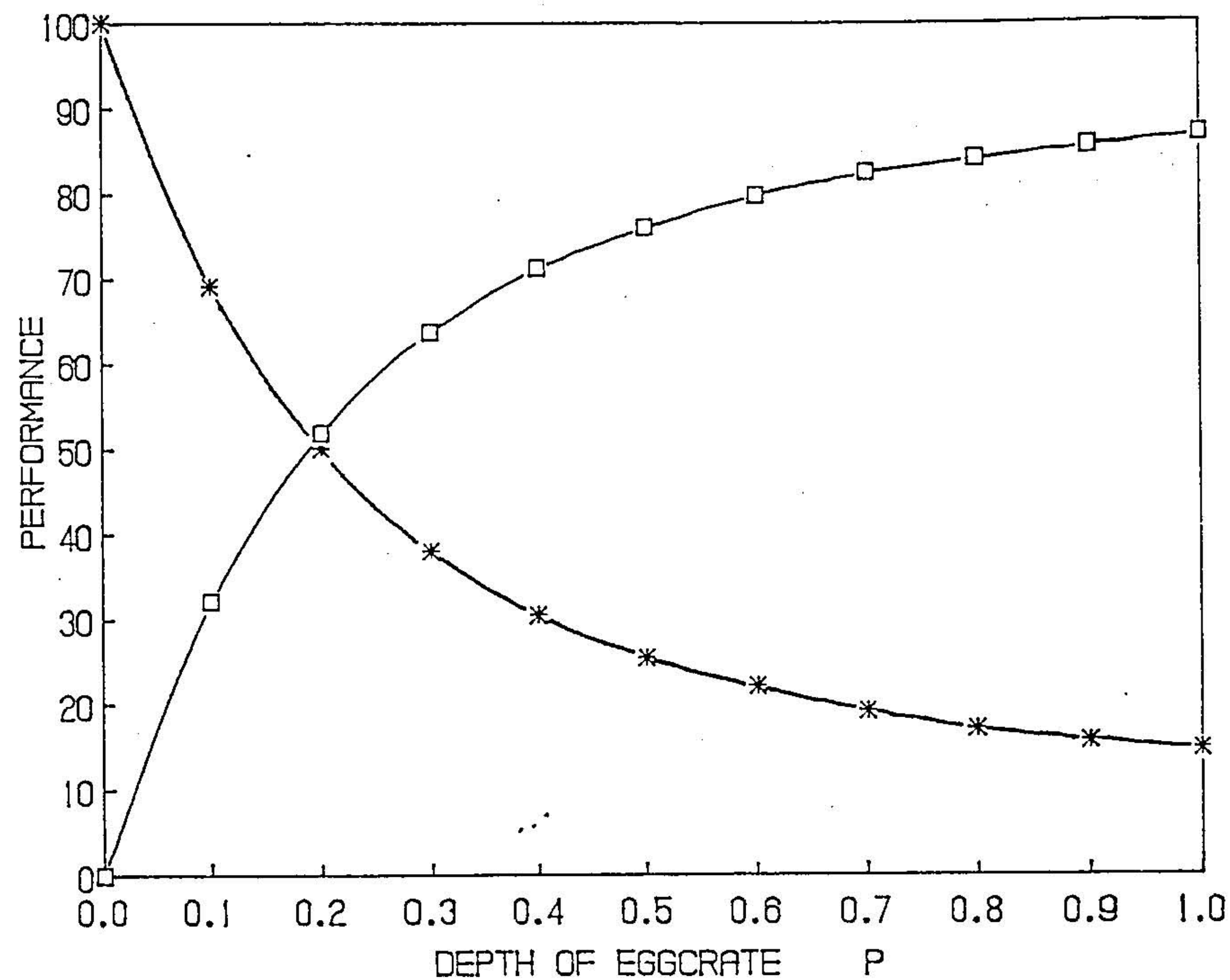


Fig (3.77)

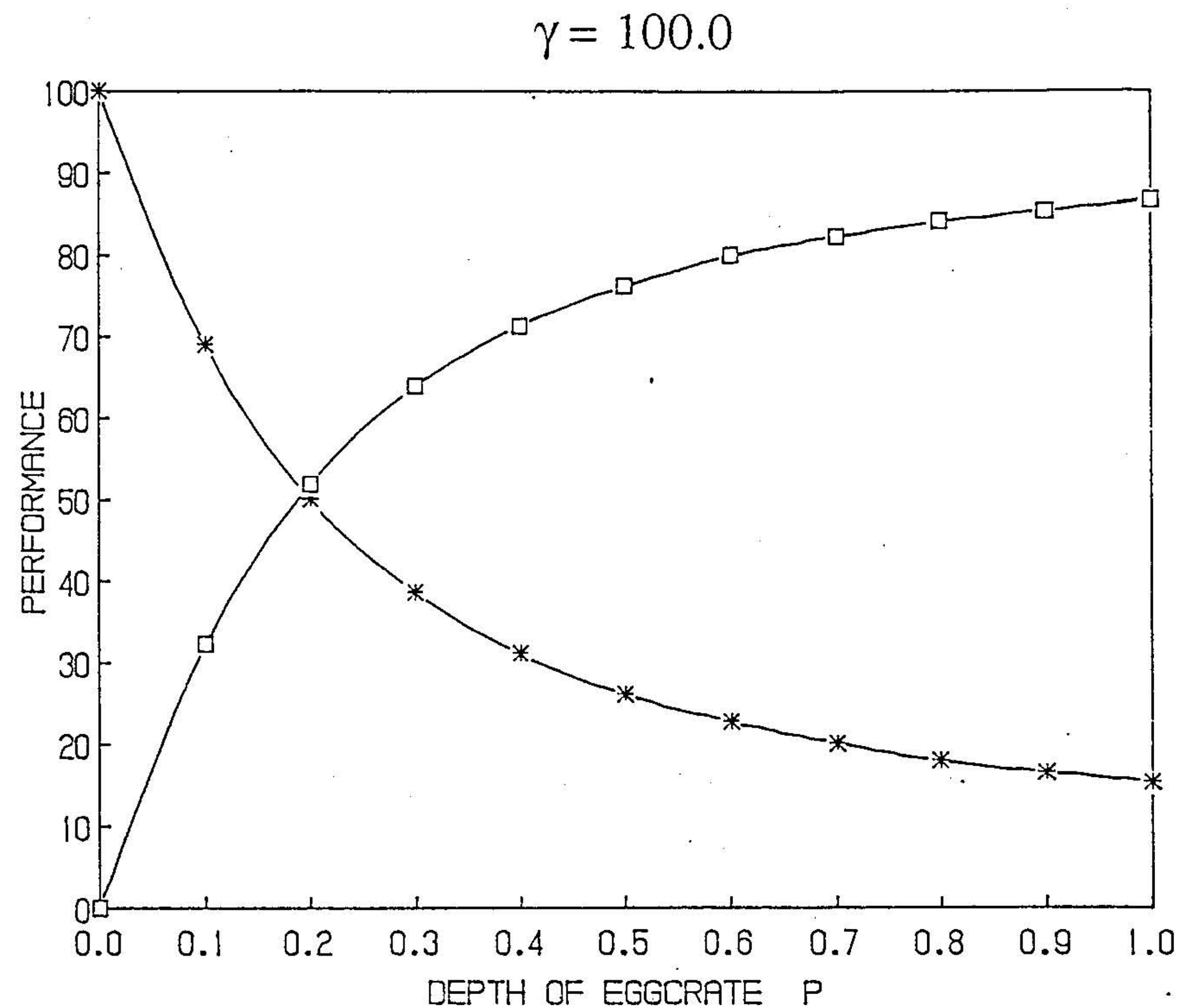

γ = 100.0
PERFORMANCE
100
90
80
70
60
50
40
30
20
10
0
0.0
0.1
0.2
0.3
0.4
0.5
0.6
0.7
0.8
0.9
1.0
DEPTH OF EGGCRATE P

Fig (3.78)

$\gamma = 110.0$

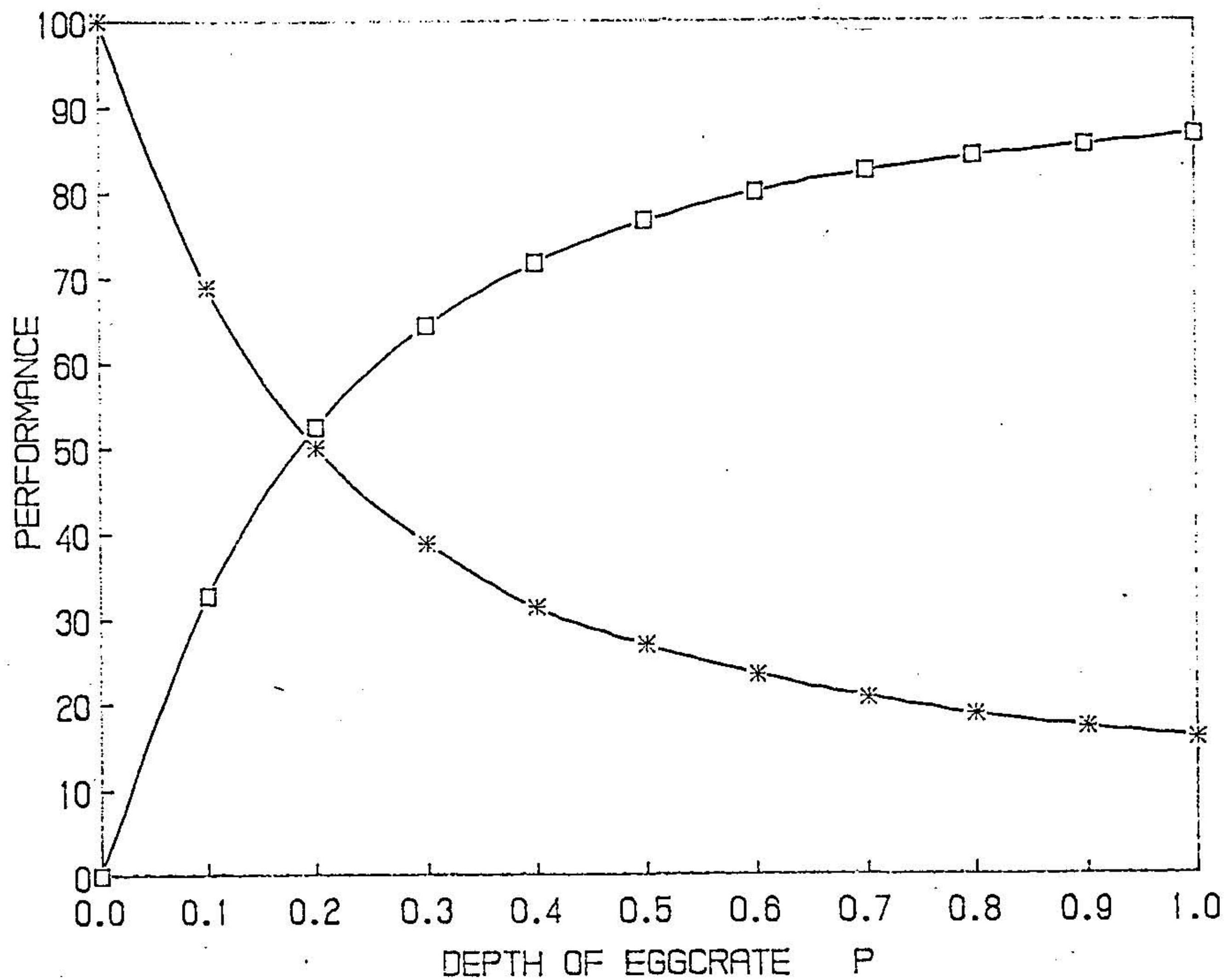


Fig (3.81)

$\gamma = 120.0$

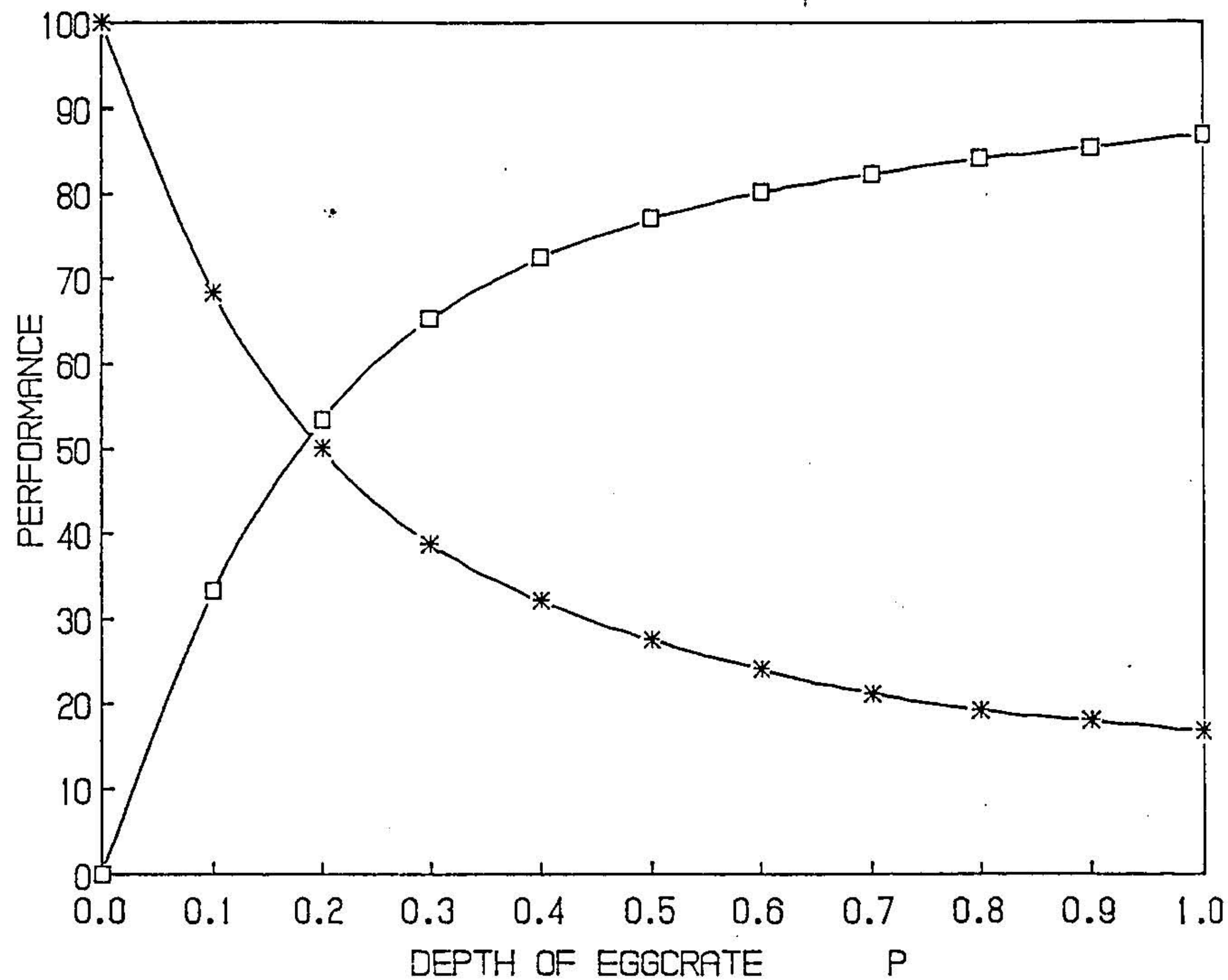


Fig (3.80)

$\gamma = 130.0$

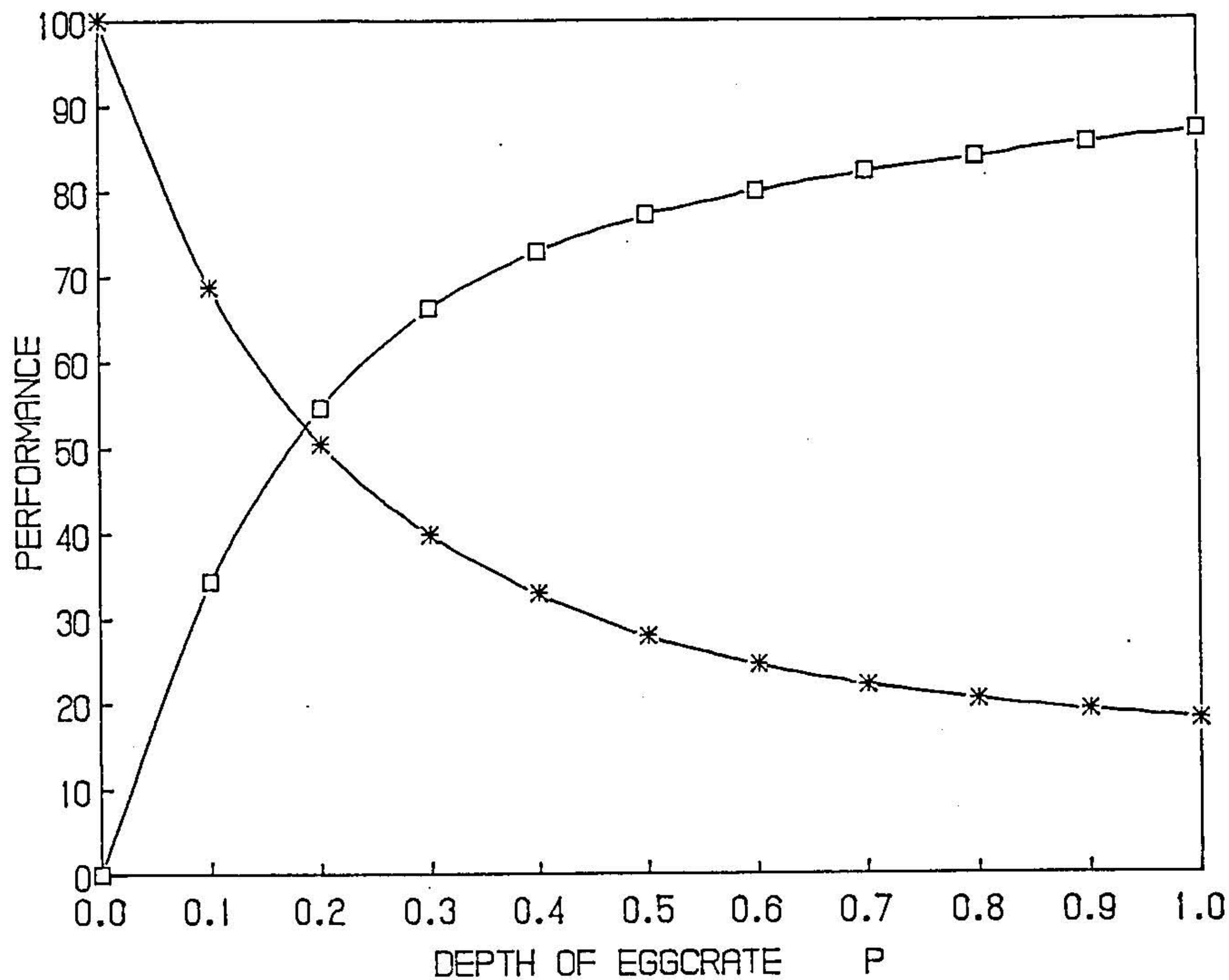


Fig (3.81)

$\gamma = 140.0$

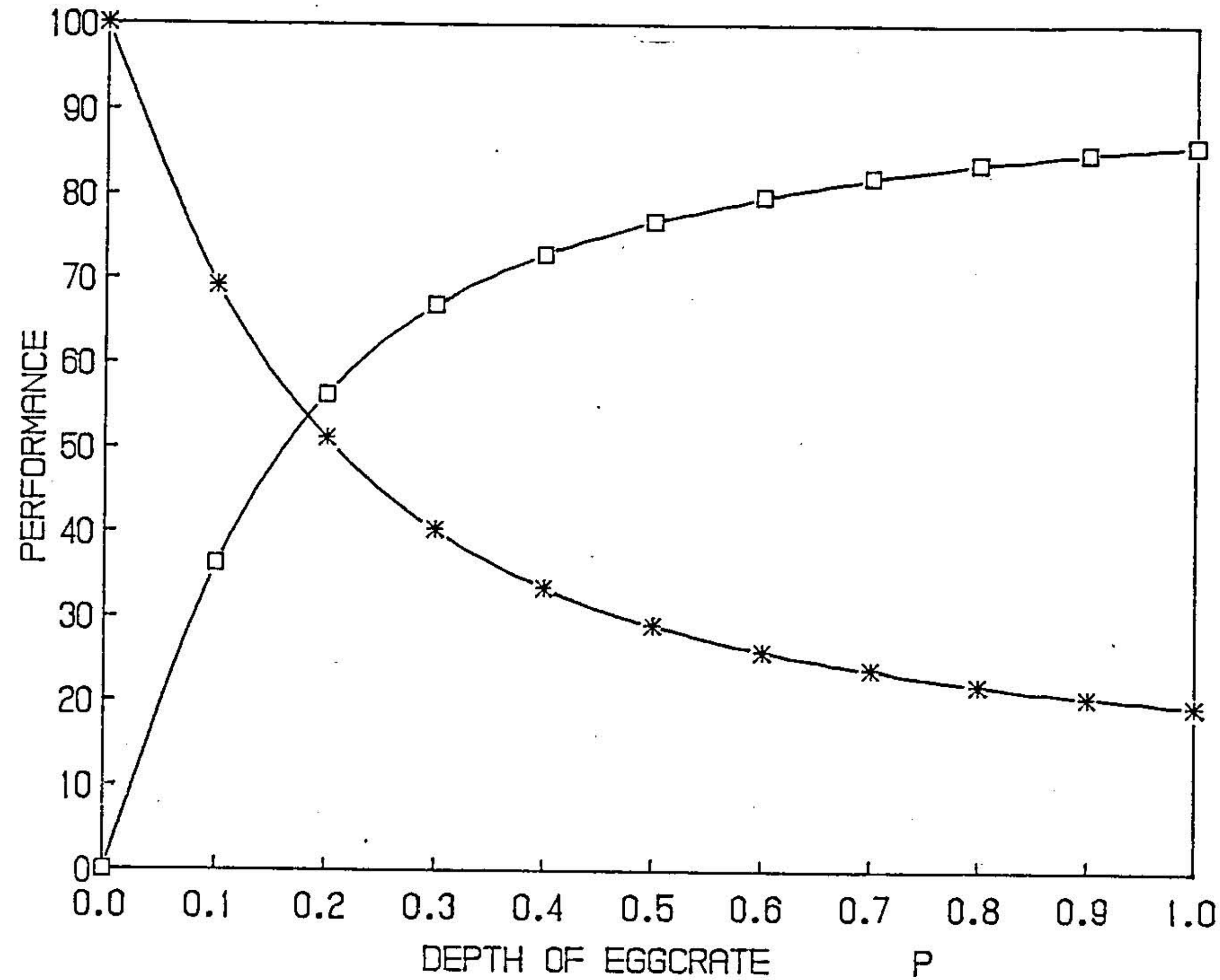


Fig (3.82)

$\gamma = 150.0$

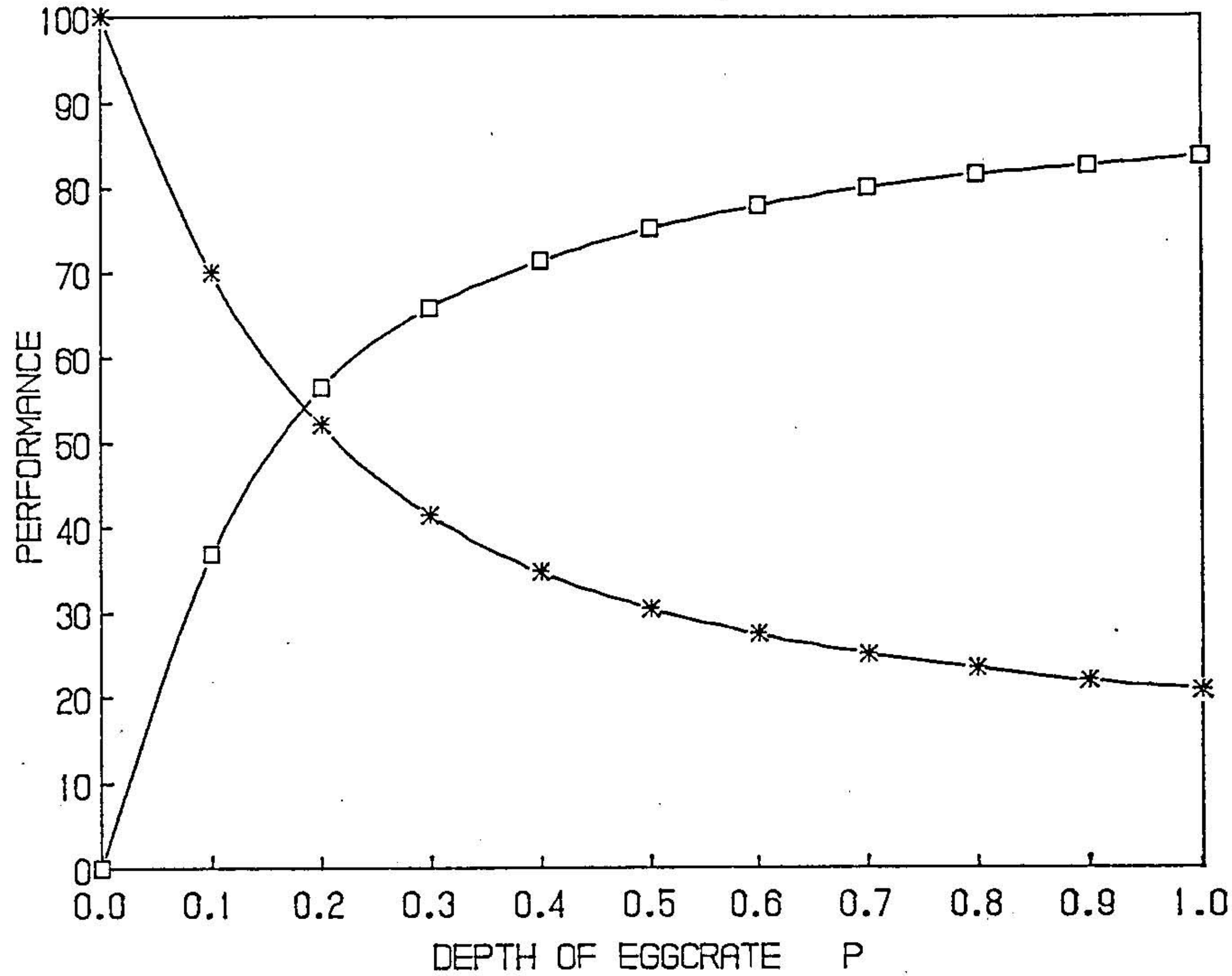


Fig (3.83)

$\gamma = 160.0$

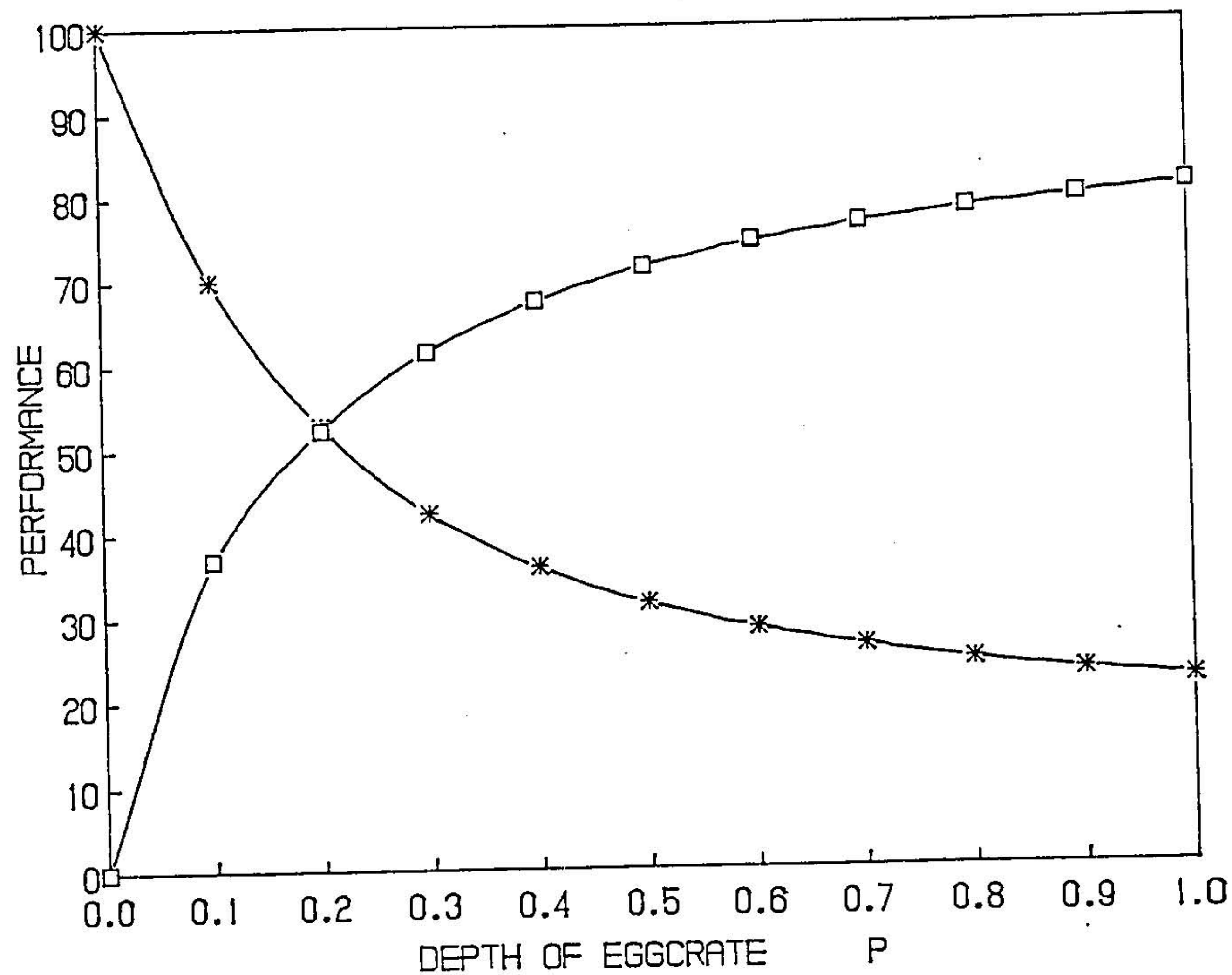


Fig (3.84)

$\gamma = 170.0$

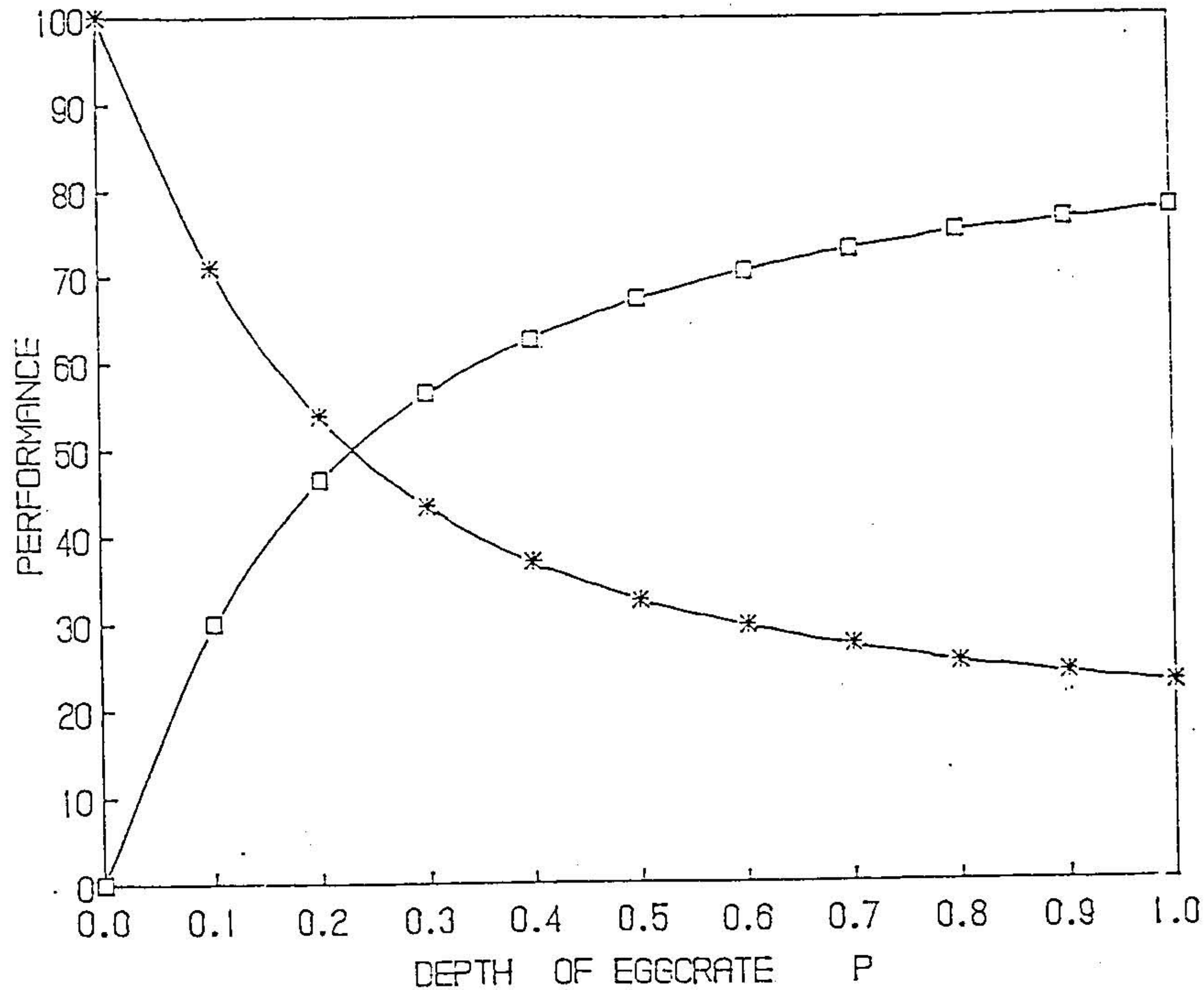


Fig (3.85)

Chapter 4
Discussion and conclusion

As expected, the use of overhang shading device or eggcrate structure results in a substantial reduction of solar radiation during summer while keeping this radiation during winter virtually unchanged.

4.1 Overhang devices:

The first set of performance curves show that there are certain values of overhang ratios above which no substantial increase in summer performance is obtaind.

The second set of performance curves show that there are certain values of overhang ratios above which no substantial decrease in winter performance is obtained. From these values of winter performance and summer performance the optimum value of overhang ratio may be obtained. Since the optimum overhang ratio is quiet dependent on the specific requirements,e.g, an office building with large internal heat generation would likely require a greater overhang than a single-family residence where heating rather than air conditioning, is the principle annual energy consumer, then the optimum overhang ratio or optimum eggcrate depth can be selected by the analysis of summer and winter performance with the specific requirements of the building.

The results for windows of an orientation range from south to north or (γ=0.0 to γ=±180), without separation of the overhang from the top of the window,are shown in Fig(3.1) to Fig(3.19), these curves contained summer and winter performances against overhang ratio, It can be seen from these curves that the rate of increase of summer performance is nearly constant and that this increase is uniform up to Z=0.4 for azimuth angle up to ±40° from South. After this ratio, the rate of increase of summer performance decreases but the performance itself increases for higher azimuth angles (50-90), the above ratio limit (0.4) increases up to (Z=0.5 - Z=0.6).

On the other hand, the rate of decrease of winter performance is nearly constant for all ratios up to (γ = ±70) from south; This rate decreases after Z=0.6 for azimuth (γ=70° -90°) from the south.

For West and East windows, winter performance and summer performance become nearly constant after (Z=0.6); This means that increasing the overhang ratio causes a slight amount in summer saving and slightly reduces winter insolation. As the surface orientation is made towards North, summer performance becomes less effective than winter performance and the rate of increase of summer performance for (γ=±120°) remains constant up to Z=0.5.This rate decreases after this ratio and becomes constant. This rate decreases as the orientation is made towards north, so that, for ($\gamma=\pm130°$) this ratio becomes=0.4 and up to ($\gamma=\pm150°$) this ratio becomes Z=0.3 until north is reached, where the rate of increasing is constant for all ratios,and summer performance becomes more desirable than all directions. However the northen windows in Amman are hardly affected by solar radiation, expect for short periods of time during early morning and late afternoon hours, therefore shading of those windows is not necessary at all. Also the decrease in winter performance is more uniform for all ratios as the window is oriented closer towards North and becomes more effective than summer performance. As moving from 0.0 to ±10° from south, it is seen that, for constant overhang ratio, the summer performance increases between Z=0.2 and Z=0.4 then decreases out of this range.Also winter performance increases up to Z=0.4 and decreases out of this range.

As (γ) is varied from ±10° to ±20° from South, the summer performance increases between Z=0.3 to Z=0.7 and decreases out of this range. This helps in the selection of the optimum direction for each overhang ratio.

The results are shown in Table(B.2) which contains the range of overhang ratios in which the summer and winter performances increase as (γ) is varried from South to East or West.

Fig(3.20) - Fig(3.29) contains summer and winter performances for the general case of overhang (i.e. when the overhang is separated from the top of window with a vertical section of the wall) with Z_2, Z_1. These curves are plotted for summer and winter performances versus Z_2 for constant Z_1.

So from these curves, for each azimuth angle, the optimum Z_2 for each Z_1 for each direction can be selected.

4.2 Eggcrate devices

As mentioned in previous sections, the optimum overhang depth depends on the specific requirements. The same statement applies also for eggcrate devices.Summer performance and winter performance were calculated for Amman city for azimuth from South to North in both directions for different window shapes (square, horizontal, and vertical).Therefor the influence of receiver azimuth and eggcrate projection on shading performance has been estimated for three window geometries namely:

a- square windows geometries, H=1.0,W=1.0

b- horizontal windows geometries, H=0.25, W=4

c- vertical windows geometries, H=4,W=0.25

For square windows, H=1.0 , W=1.0 the results for summer and winter performances are shown in Fig(3.30) - Fig(3.48).

These curves show that, for azimuth angles from (±0.0 - ±40°) from South, the rate of increase in summer performance and rate of decrease in winter performance are substantially constant up to P=(0.3 - 0.4) in which the two performances are equal. After this range, the rate of increase in summer performance and rate of decrease in winter performance decreases with increasing depth of eggcrate.

For azimuth angles ±50 to ±60 the two performances become equal between (0.4-0.5). The rate of increasing in summer performance and the rate of decrease in winter performance become less after this point.

For azimuth angle from ±70 to 120° from South, the rate of of increase in summer performance and rate of decrease in winter performance are similar for these directions, in which those rates nearly constant until P=(0.5-0.6) in which the two performances become equal. After this point the rate is less than before these points.

As the orientation is varied towards North in both directions, the rate of decrease in Winter performance and rate of increase in Summer performance become higher than before and the point in which both performances are equal becomes less where P=(0.4-0.5).

For horizontal and vertical windows characterized by H=4.0 and W=0.25 for horizontal window and H=0.25 and W=4.0 for vertical window the summer and winter performances are shown in Fig(3.49) -

Fig(3.67), for vertical windows and in Fig(3.68) - Fig(3.86) for horizontal windows.

From these curves it can be seen that the summer performance for horizontal windows is more effective than vertical for most directions. Also the Summer performance for vertical windows is more effective than square windows.

The opposite is true for winter performance in which square windows are more effective than vertical, and vertical windows are more effective than horizontal.

The percentage of beam radiation on shaded window to total actual radiation on shaded window is calculated for South and East directions for some hours in the day for some monthes of the year. The results are shown in table(4.1), table(4.2).

The results show the difference between beam radiation and total radiation on shaded window, this means that the calculation which depend on beam radiation only and neglects other types of radiation has a high error which reaches up to more than 50% in some cases.

Finally, since all calculations are done for eggcrate structures using Collares-Pereira equation[10], and to compare between this equation and the measured hourly radiation for Amman, the average error using this equation was calculated for three months which are March, January, and July from (8-12) morning and the average error for March was 6.725%

and for January was 6.3% and for July was 5.2%.

Also comparison between Collares-Pereira relation[10], eq.(2.36) and Jain with Alsaad constants for Amman[11], eq.(2.39) was made by calculating Summer and Winter performances for South window, the results produced much closer performances to that obtained by using Collares-Pereira relation.

The results are shown in table(4.3).

Conclusions

From results which has been calculated for overhang and eggcrate,the following can be concluded:-

1- For windows facing (±10°) from South, the overhang shading can queit effectively reduce summer insolation without an appreciable reduction in winter insolation.

2- For windows facing up to (±40°) from South, the overhang ratios greater than Z=0.4, provide alittle additional reduction in summer insolation, and continue to reduce the winter insolation.

3- For windows facing (±50° to ±70°) from south, the overhang ratios greater than 0.5 provide alittle additional reduction in summer insolation, and for windows facing (±70° to ±90°) this ratio limit becomes 0.6.

4- For windows facing up to ±70° from South, the reduction in winter insolation is uniform with increasing of overhang ratios.

5- For windows (80°-110°) from south, the overhang ratios greater than Z=0.6,will provide very little what in summer and winter insolation and this ratio changes to Z=0.5 for windows facing (110°-120°) and changes to Z=0.4 for (γ=±130-140°).

6- For windows towards North are hardly affected by solar radiation, therefore shading of those windows is not necessary.

7- As moving from South towards West or East, the summer performance increases for some ranges of overhang ratios and winter performance increase for some ranges of overhang ratios, the results are shown in Appendix B Table(B.2).

8- For windows of the general case, where the overhang is separated by asection wall from the window, and for all direction between South, West or East, which have Z_2 greater than (1-4) for all values of Z_1, the reduction in both summer and winter insolation is not significant.

9- For all types of windows facing South and for directions up to (±40°) from South, the depth of eggcrate greater than (0.3-0.4), provide a small reduction in summer and winter insolations.

10- For square windows,increasing the depth of eggcrate,provides nearly a uniform reduction in summer and winter insolation.

11- For horizontal windows,the effectiveness of shading decreases with the increase of window azimuth from South to East or West, then increases with the most values of depth of eggcrate as moving to West or East North,then decreases to North.

12- For vertical windows, the effectiveness of shading decreases with the increase of window azimuth from South to East or

West for most values of depth of eggcrate and increases as moving towards North.

13- For square windows, the effectiveness of shading decreases with the increase of window azimuth from South to East or West for most values of depth of eggcrate and increases as moving towards North, expect directions around North.

14- For horizontal and vertical windows, the depth of eggcrate greater than P=(0.3 -0.4),provide a small reduction in summer and winter insolation.This is applies for all directions from South to North.

15- For windows in any direction, shading of horizontal ones is more effective than shading of vertical ones.

16- The effectiveness of shading of vertical windows more effective than shading square ones for direction from South nearly to West or East.

Recommendations

The literature survey together with the present work suggest that there are areas which need further theoretical investigations. Some of these areas are mentioned in this section as follows:-

- Studing the theoretical analysis of the using vertical shading structures.
- Studing the effect of shading on neighboring buildings on shading devices performances.

Tabel (4.1): Ratio of hourly beam radiation to hourly total radiation on shaded East window (p=0.3)

Month	Hour	Ratio of beam radiation to total radiation
Jun	8 morning 9 morning 10 morning	0,7349 0,5854 0,3615
Feb.	8 morning 9 morning 10 morning	0,7527 0,6046 0.3845
Mar.	8 morning 9 morning 10 morning	0.7712 0.6237 0.4029
April.	8 morning 9 morning 10 morning	0.7871 0.6380 0.4099
May	8 morning 9 morning 10 morning	0.7842 0.6446 0.4053
June.	8 morning 9 morning 10 morning	0.7489 0.6460 0.3989
July.	8 morning 9 morning 10 morning	0.7646 0.6455 0.4019
Aug.	8 morning 9 morning 10 morning	0.7920 0.6413 0.4090
Sep.	8 morning 9 morning 10 morning	0.7779 0.6300 0.4073
Oct.	8 morning 9 morning 10 morning	0.7590 0.6114 0.3918
Nov.	8 morning 9 morning 10 morning	0.7398 0.5906 0.3632
Dec.	8 morning 9 morning 10 morning	0.7296 0.5791 0.3537

Tabel (4.2): Ratio of hourly beam radiation to hourly total radiation on shaded South window (p=0.3)

Month	Hour	Ratio of beam radiation to total radiation
Jun.	8 morning	0.886
	9 morning	0.829
	10 morning	0.795
	11 morning	0.778
	12 afternoon	0.7728
	1 afternoon	0.7060
	2 afternoon	0.6433
	3 afternoon	0.5773
	4 afternoon	0.4955
Feb.	8 morning	0.8032
	9 morning	0.7486
	10 morning	0.7192
	11 morning	0.7043
	12 afternoon	0.6997
	1 afternoon	0.6270
	2 afternoon	0.5544
	3 afternoon	0.4703
	4 afternoon	0.3504
Oct.	8 morning	0.7540
	9 morning	0.7044
	10 morning	0.6786
	11 morning	0.6657
	12 afternoon	0.6618
	1 afternoon	0.5868
	2 afternoon	0.5096
	3 afternoon	0.4158
	4 afternoon	0.2745
Nov.	8 morning	0.8685
	9 morning	0.8110
	10 morning	0.7783
	11 morning	0.7612
	12 afternoon	0.7556
	1 afternoon	0.6876
	2 afternoon	0.6225
	3 afternoon	0.5523
	4 afternoon	0.4623

Tabel (4.3): Comparison between Summer and Winter performances using Collares-Pereira equation and Jain model with Alsaad constants for square eggcrate for South windows .

Depth of egg-crate	Summer performance		Winter performance	
	Using Collares-Pereira	Using Jain	Using Collares-Pereira	Using Jain
0.1	0.23	0.223	0.862	0.86
0.2	0.397	0.388	0.74	0.74
0.3	0.513	0.504	0.633	0.634
0.4	0.596	0.586	0.538	0.54
0.5	0.664	0.651	0.460	0.463
0.6	0.72	0.703	0.392	0.396
0.7	0.759	0.742	0.331	0.338
0.8	0.794	0.775	0.284	0.293

Nomeclature

Fd^* : Geometrical factor for albedo relected by overhang.

H : Daily irradiation.

$\overline{H}$: Monthly average daily irradiation.

$\overline{H}^*$: Monthly average daily irradiation of shaded window by overhang.

$\overline{K}_t$: Monthly average clearness index.

$\overline{R}_b$: Surface to horizontal avearage beam radiation ratio.

Sd^* : Geometrical factor for diffuse radiation of overhang.

β : Surface tilt angle.

γ : Surface azimuth angle (east negative, west positive).

δ : Decliantion angle.

ρ : Reflectivity.

ϕ : Latitude angle.

ω : Hour angle, morning negative, afternoon positive.

γ : Solar azimuth from south.

α : Solar altitude.

A : Receiver area (m^2).

P' : Dimensional projection depth (m) of eggcrate.

P : Non-dimensional projection depth of eggcrate.

$F_{i,s}$,$F_{i,g}$: ith view factors of eggcrate surface to sky and ground.

$F_{r,s}$,$F_{r,g}$: View factor for receiver to sky and ground.

f : direct beam irradiated area fraction.

h' : Dimensional receiver height (m).

h : Non-dimensional receiver height of eggcrate.

w′ : Dimensional receiver width (m) of eggcrate.

w : Non-dimensional receiver width of eggcrate.

z : Overhang ratio.

Subscripts

b : Beam component.

d : Diffuse component.

h : Horizontal.

o : Extraterrestrial.

sr : Sunrise on surface.

ss : sent on surface.

s : sunrise on horizontal.

g : ground or ground-reflected.

i : index, identifies eggcrate surface (i=1,2,3,4).

s : Shaded fraction.

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APPENDIX A

General Definitions

Following are the basic terms in common use to describe direct solar radiation

Beam radiation:

The solar radiation received from the sun without having been scattered by the atmosphere.

(Beam radiation is often referred to as a direct solar radiation; to avoid confusion between subscripts for direct and diffuse, the term beam radiation is used).

Diffuse radiation:

The solar radiation received form the sun after it's direction has been changed by scattering by the atmosphere. (Diffuse radiation is referred to in some meteorological literature as sky radiation or solar radiation.

Total solar radiation:

The sum of the beam and the diffuse radiation on a surface.

(the most common measurements of solar radation are total radiation on horizontal surface, often referred to as global radiation).

Irradiance: the rate at which radiant energy is inicident on the surface, per unit area of surface.

The solar constant(I_{sc}):

The solar constant is the energy from the Sun, per unit time received on a unit area of surface perpendicular to the direction of propagation of the radiation, at the earth's mean distance from the Sun, outside of the atmosphere.

The extraterrestrial radiation:

The radiation that would be received in the absence of the atmosphere.

Altitude of the sun(α):

The angle which a direct ray from the sun makes with the horizontal at a particular place on the surface of the earth at a particular time and date.

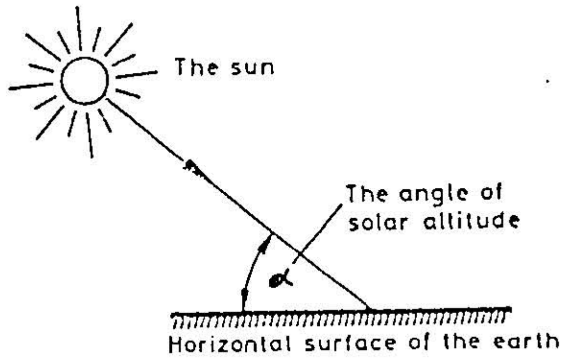
It is illustrated in Fig(A.1). For given date and time, the sun's altitude is different at different places over the world.

Solar azimuth angle (γ_S):

This is the angle which the horizontal component of a direct ray from the sun makes with the true North-South axis. It may be expressed in degrees West or Eeast of South, as illustrated in Fig(A.2).

Surface azimuth angle(γ):

That is; the deviation of the projection of the normal on a horizontal plane from local meridian with zero due South, Eeast



Fig(A.1): solar altitude

(b)

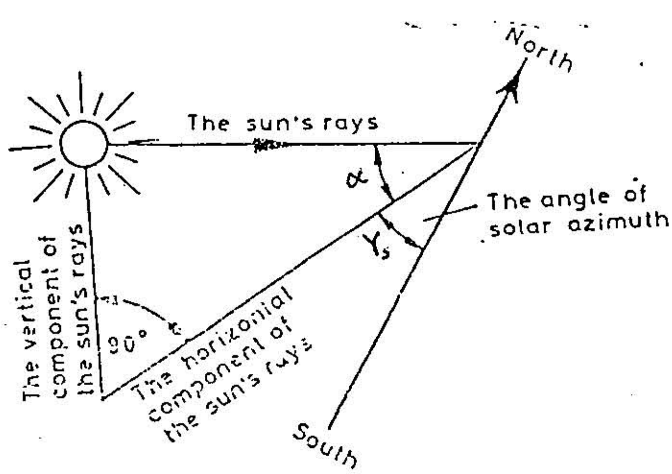


Fig (A.2): solar azimuth

negative,West positive, $-180^\circ \leq \gamma \leq 180^\circ$ as illustrated in Fig(A.3)

Zenith angle (θ_z): The angle subtended by avertical line to Zenith (i.e., the point directly overhead) and the line to sight to sun. as illustrated in Fig(A.3).

Declination angle (δ):

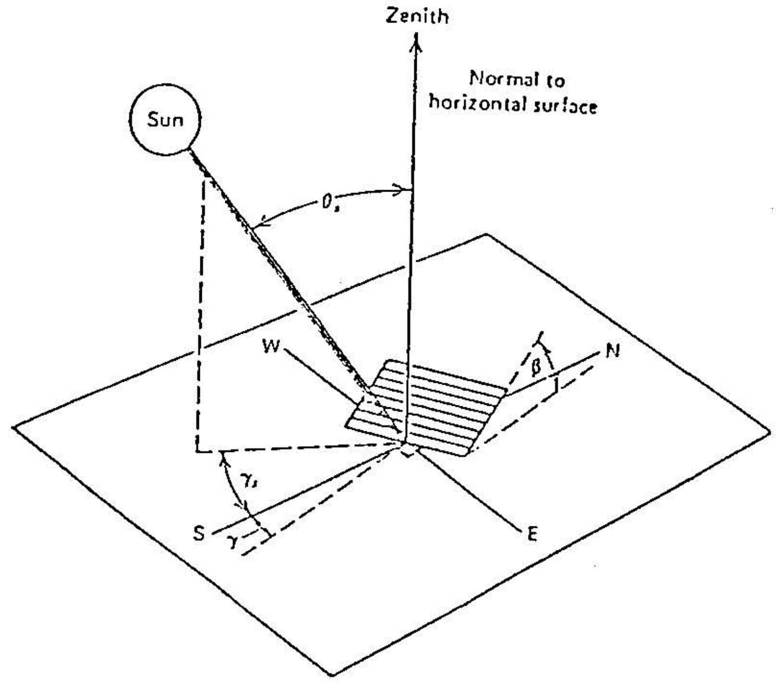
This is the angular displacement of the sun from the plane of the earth's equator. The value of the declination will vary throughout the year between $+23\frac{1}{2}^\circ$ and $-23\frac{1}{2}^\circ$ because the axis of the earth is tilted at an angle of about $23\frac{1}{2}^\circ$ to the axis of the plane in which it orbits the sun.

Declination is expressed in degrees north or south (of the equator). the geometry of declination is illustrated in Fig(A.4)

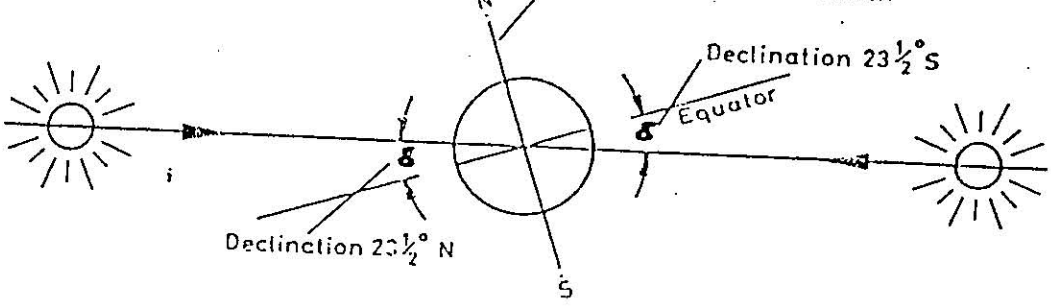
Wall solar azimuth(c): This is the angle the horizontal component of the sun's ray makes with a direction normal to a particular wall. It is illustrated in Fig(A.5). where it can be seen that this angle, referring as it does to direct radiation, can have a value between 0° and 90° and go only. when the wall is shadow ($C > 90^\circ$) the value of C has no meaning.

Latitude angle(ϕ):

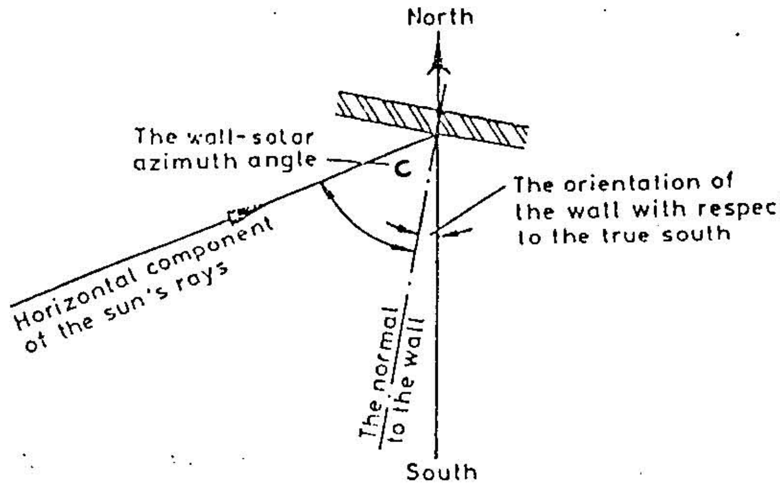
The latitude of a place on the surface of the earth is it's angular



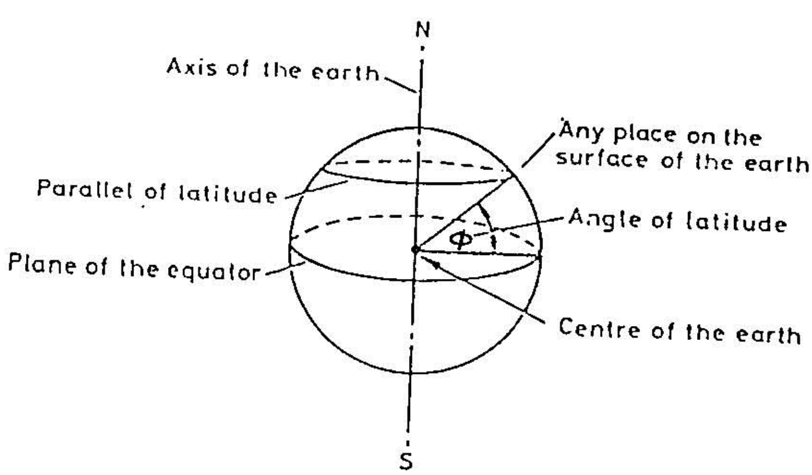
Fig(A.3): surface azimuth angle, zenith angle and tilt angle



Fig(A.4): solar declination in June and December



Fig(A.5): wall - solar azimuth



Fig(A.6):The latitude of aplace on the surface of the earth displacement above or below the plane of the equator, measured from the center of the earth. It is illustrated in Fig(A.6). The value of latitude angle between - 90° to + 90°.

Longitude angle(L): This is the angle which a semi-plane through the poles, and a particular place on the surface, makes with a similar semi-plane through Greenwich. The semi-plane through Greenwich is an arbitrary zero, and the line it makes in cutting the earth's surface is measured Eeast or West of Greenwich meridian.

Longitude is measured east or west Greenwich and so its value lies between 0° and 180°. Latitude and Longitude together are co.ordinates which locate any point on the surface of earth .

Sun Time (T):

This is the time in hours, before or after noon, noon being defined as the time when the sun is highest in the sky.

Hour angle(ω):

This is the angular displacement of sun Eeast or West of the local meridian due to rotation of the earth on it's axis at 15° per hours, morning negative, afternoon positive.

Tilt angle (β):

Is the angle between the plane surface in question and horizontal. $0° \leq \beta \leq 180°$, $\beta > 90°$ means that the surface has (adown word) facing component Fig(A.3).

Solar Angle determination

In this section, the most important solar angles are to be determined referring to Ref [9], in which they are used in this work.

Declination angle(δ):-

The declination δ, can be found from equation of cooper (1969):-

$$\delta = 23.45 \, Sin(360 \times \frac{(284 + n)}{365}) \quad \text{..2.1}$$

Where n is the day of the year, n given in table ....(A.1)

Angle of incidence (θ):-

The equation relating the angle of the incidence of beam radiation,θ, given by:-

$$Cos\,\theta = Sin\,\delta\,Sin\,\phi\,Cos\,\beta - Sin\,\delta\,Cos\,\phi\,Sin\,\beta\,Cos\,\gamma + Cos\,\delta\,Cos\,\phi\,Cos\,\beta\,Cos\,\omega + Cos\,\delta\,Sin\,\phi\,Sin\,\beta\,Cos\,\gamma\,Cos\,\omega + Cos\,\delta\,Sin\,\beta\,Sin\,\gamma\,Sin\,\omega \quad \text{..................(A.2)}$$

For vertical surfaces, β =90, angle of incindence becomes

$$Cos\,\theta = -\,Sin\,\delta\,Cos\,\phi\,Cos\,\gamma + Cos\,\delta\,Sin\,\phi\,Cos\,\gamma\,Cos\,\omega + Cos\,\delta\,Sin\,\gamma\,Sin\,\omega \quad \text{..(A.3)}$$

For horizontal surface, β = 0, and the angle of incidence is the zenith angle of the sun, θ_Z, becomes:-

$$Cos\theta_Z = Cos\,\delta\,Cos\,\phi\,Cos\,\omega + Sin\,\delta\,Sin\,\phi \quad \text{..........................(A.4)}$$

The above equation can be solved for sunet hour angle ω_s,when $\theta_Z = 90\,°$, So:

$$\cos \omega_S = -\tan \phi \tan \delta \quad \text{.........(A.5)}$$

Solare azimuth angle (γ_s):

The solar azimuth angle, can be given by either one of the following equation:

$$\sin(\gamma_s) = \frac{\cos \delta \sin \omega}{\sin \theta_Z} \quad \text{.........(A.6)}$$

$$\tan \gamma_s = \frac{\sin(\omega)}{\sin \phi \cos \omega - \cos \phi \tan \delta} \quad \text{.........(A.7)}$$

Hours angle(ω):

Which is the angular displacement of the sun form noon which given by:-

$$\omega = \frac{360}{24} \times T \quad \text{.........(A.8)}$$

Or , in other words, 1 hour corresponds to 15° of angular displacement.

Those angles are be used, mostly in this work in order to estimate the average daily radiation on arbitrary surface.

APPENDIX B

Table B.1 : Monthly average daily extraterrestrial radiation, KJ / m^2 and average daily radiation on horizontal (KJ/m^2) and $\overline{K}_t$ for Amman city .

Month	$\overline{H}$ KJ/m^2	$\overline{H}_o$ KJ/m^2	$\overline{K}_t$
Jan.	9381	19909	0.471
Feb.	10735	24664	0.435
Mar.	16668	30540	0.546
Apr.	20451	36096	0.566
May.	24987	39635	0.630
June	28684	40923	0.701
July	28101	40183	0.699
Aug.	25862	37381	0.692
Sep.	21931	32460	0.676
Oct.	20725	26353	0.786
Nov.	11314	20999	0.539
Dec.	10155	18553	0.547

Table (B.2) optimum directions table for constant overhang ratio.

direction moving from South to West or East	range of over hang ratio in which summer perf. increases	ranges of over ratio in which winter perf. increases
0 - ±10°	Z= 0.2 - Z = 0.4	Z= 0.2 - Z = 0.4
±10° - ±20°	Z=(0.3 - 0.7)	Z=(0.0 - 0.5)
±20° - ±30°	Z=(0.4 - 1.0)	Z=(0.0 - 1.0)
±30° - ±40°	Z=(0.5 - 1.0)	Z=(0.5 - 1.0)
±40° - ±50°	Z=(0.6 - 1.0)	Z=(0.0 - 1.0)
±50° - ±60°	Z=(0.6 - 1.0)	Z=(0.0 - 0.7)
±60° - ±70°	Z=(0.6 - 1.0)	Z=(0.0 - 0.3)
±70° - ±80°	Z=(0.2 -0.5)	Z=(0.0 - 0.1)
±80° - ±90°	Z=(0.0 - 0.6)	Z≠

Table (B.3)summer and winter radiation on shaded and unshaded window with overhang for $\gamma = 0.0$

Z	HWu	HWs	W.P	HSu	HSs	D.S	S.P
.100	75342	69423	.921	73232	63474	9758	.133
.200	75342	63602	.844	73232	55443	17789	.243
.300	75342	57991	.770	73232	49629	23603	.322
.400	75342	52740	.700	73232	45041	28191	.385
.500	75342	48316	.641	73232	40864	32368	.442
.600	75342	44054	.585	73232	37426	35806	.523
.700	75342	39646	.526	73232	34948	38284	.555
.800	75342	36555	.485	73232	32586	40646	.614
.900	75342	33528	.445	73232	28244	44988	.623
1.000	75342	30554	.406	73232	27583	45649	.631
1.100	75342	26956	.358	73232	26997	46235	

Z : overhang ratio.
HWu : Total winter radiation on unshaded window KJ/m^2.
HWs : Total winter radiation on shaded window KJ/m^2.
WP : Winter performance.
HSu : Total summer radiation on unshaded window KJ/m^2.
HSs : Total summer radiation on shaded window KJ/m^2.
S.P : Summer performance.
D.S = HSu - HSs. KJ/m^2.

Table (B.4)summer and winter radiation on shaded and unshaded window with overhang for $\gamma = 10.0$

Z	HWu	HWs	W.P	HSu	HSs	D.S	S.P
.100	74980	69130	.922	74489	64812	9677	.130
.200	74980	63400	.846	74489	56405	18085	.243
.300	74980	57903	.772	74489	50333	24156	.324
.400	74980	52716	.703	74489	45501	28988	.389
.500	74980	47926	.639	74489	41648	32841	.441
.600	74980	43889	.585	74489	38152	36337	.488
.700	74980	40121	.535	74489	34710	39779	.534
.800	74980	36104	.482	74489	34675	42814	.575
.900	74980	32907	.439	74489	30363	44126	.592
1.000	74980	29368	.392	74489	28590	45899	.616
1.100	74980	26759	.357	74489	26997	47492	.638

Z : overhang ratio.
HWu : Total winter radiation on unshaded window KJ/m^2.
HWs : Total winter radiation on shaded window KJ/m^2.
WP : Winter performance.
HSu : Total summer radiation on unshaded window KJ/m^2.
HSs : Total summer radiation on shaded window KJ/m^2.
S.P : Summer performance.
D.S = HSu - HSs. KJ/m^2.

Table (B.5) summer and winter radiation on shaded and unshaded window with overhang for $\gamma = 20.0$

Z	HWu	HWs	W.P	HSu	HSs	D.S	S.P
.100	73868	68190	.923	78028	68685	9343	.120
.200	73868	62673	.848	78028	60037	17990	.231
.300	73868	57424	.777	78028	52460	25567	.328
.400	73868	52485	.711	78028	47151	30876	.396
.500	73868	47517	.643	78028	42818	35210	.451
.600	73868	42995	.582	78028	39616	38412	.492
.700	73868	39341	.533	78028	36233	41795	.536
.800	73868	35546	.481	78028	33583	44445	.570
.900	73868	31680	.429	78028	31967	46061	.590
1.000	73868	28203	.382	78028	30072	47956	.615
1.100	73868	24674	.334	78028	28011	50017	.641

Table (B.6) summer and winter radiation on shaded and unshaded window with overhang for $\gamma = 30.0$

Z	HWu	HWs	W.P	HSu	HSs	D.S	S.P
.100	72013	66561	.924	83045	74229	8817	.106
.200	72013	61305	.851	83045	65990	17055	.205
.300	72013	56341	.782	83045	57083	25962	.313
.400	72013	51668	.717	83045	49716	33329	.401
.500	72013	46982	.652	83045	44792	38254	.461
.600	72013	42243	.587	83045	41182	41864	.504
.700	72013	38448	.534	83045	38021	45024	.542
.800	72013	35063	.487	83045	34815	48230	.581
.900	72013	31786	.441	83045	32712	50334	.606
1.000	72013	29001	.403	83045	30758	55287	.630
1.100	72013	26980	.375	83045	28693	54352	.654

Table (B.7) summer and winter radiation on shaded and unshaded window with overhang for $\gamma = 40.0$

Z	HWu	HWs	W.P	HSu	HSs	D.S	S.P
.100	69991	64855	.927	87857	79512	8344	.095
.200	69991	59954	.851	87857	71612	16244	.185
.300	69991	55376	.791	87857	63126	24731	.281
.400	69991	51033	.729	87857	53627	34230	.390
.500	69991	46716	.667	87857	47049	40807	.464
.600	69991	42378	.605	87857	42268	45589	.519
.700	69991	38116	.545	87857	39190	48667	.554
.800	69991	35062	.501	87857	35876	51980	.592
.900	69991	31997	.457	87857	32951	54905	.625
1.000	69991	29069	.415	87857	30914	56942	.648
1.100	69991	27004	.386	88810	29046	54352	.672

Table (B.8) summer and winter radiation on shaded and unshaded window with overhang for $\gamma = 50.0$

Z	HWu	HWs	W.P	HSu	HSs	D.S	S.P
.100	67692	62898	.929	91832	83885	7948	.087
.200	67692	58366	.862	91832	76191	15641	.170
.300	67692	54155	.700	91832	67864	23968	.261
.400	67692	50070	.740	91832	58582	33250	.362
.500	67692	46016	.680	91832	49110	42722	.465
.600	67692	41852	.618	91832	43523	48309	.526
.700	67692	37586	.555	91832	39459	52373	.570
.800	67692	34323	.507	91832	35928	55904	.609
.900	67692	31253	.462	91832	32626	59206	.645
1.000	67692	28119	.415	91832	30496	61336	.668
1.100	67692	25695	.380	91832	28335	63497	.691

Table (B.9)summer and winter radiation on shaded and unshaded window with overhang for $\gamma = 60.0$

Z	HWu	HWs	W.P	HSu	HSs	D.S	S.P
.100	64936	60477	.931	94690	87078	7163	.080
.200	64936	56292	.867	94690	79462	15229	.161
.300	64936	52340	.806	94690	71138	23552	.249
.400	64936	48443	.746	94690	61887	32804	.346
.500	64936	44462	.685	94690	51678	43012	.454
.600	64936	40352	.621	94690	43562	51128	.540
.700	64936	36047	.555	94690	38674	56017	.592
.800	64936	32328	.498	94690	34934	59757	.631
.900	64936	38813	444	94690	31696	62995	.665
1.000	64936	25603	.394	94690	29473	65218	.689
1.100	64936	22841	.352	94690	27246	67445	.712

Table (B.10)summer and winter radiation on shaded and unshaded window with overhang for $\gamma = 70.0$

Z	HWu	HWs	W.P	HSu	HSs	D.S	S.P
.100	61641	57501	.933	96249	88890	7359	.076
.200	61641	53606	.870	96249	81198	15051	.156
.300	61641	49793	.808	96249	72684	23565	.245
.400	61641	45897	.745	96249	63170	33079	.344
.500	61641	41802	.678	96249	52649	43600	.453
.600	61641	37327	.606	96249	42361	53888	.560
.700	61641	32467	.527	96249	36807	59442	.618
.800	61641	28314	.459	96249	32869	63380	.659
.900	61641	24437	396	96249	30142	66107	.687
1.000	61641	21490	.349	96249	27831	68418	.711
1.100	61641	18580	.301	96249	26997	69252	.720

Table (B.11)summer and winter radiation on shaded and unshaded window with overhang for $\gamma = 80.0$

Z	HWu	HWs	W.P	HSu	HSs	D.S	S.P
.100	67806	53694	.934	96404	89157	7247	.075
.200	67806	50188	.868	96404	81151	15253	.158
.300	67806	46211	799	96404	72079	24325	.252
.400	67806	41814	.723	96404	62009	34396	.357
.500	67806	37019	.640	96404	51088	45316	.470
.600	67806	31883	.552	96404	39688	56716	.588
.700	67806	26492	.458	96404	33858	62546	.649
.800	67806	22284	.385	96404	30395	66010	.685
.900	67806	19064	330	96404	28244	68160	.707
1.000	67806	16349	.283	96404	27583	68821	.714
1.100	67806	14949	.259	96404	26997	69408	.720

Table (B.12)summer and winter radiation on shaded and unshaded window with overhang for $\gamma = 90.0$

Z	HWu	HWs	W.P	HSu	HSs	D.S	S.P
.100	59492	49584	.927	95123	87533	7589	.080
.200	59492	45196	.845	95123	78768	16354	.172
.300	59492	40399	755	95123	68999	26124	.275
.400	59492	35242	.659	95123	58361	36762	.386
.500	59492	29783	.557	95123	47015	48108	.506
.600	59492	24086	.450	95123	35140	59982	.361
.700	59492	19024	.356	95123	30290	64832	.682
.800	59492	16246	.304	95123	28993	66129	.695
.900	59492	15726	294	95123	28244	66878	.703
1.000	59492	15314	.286	95123	27583	67540	.710
1.100	59492	14949	.279	95123	26997	68126	.716

Table (B.13)summer and winter radiation on shaded and unshaded window with overhang for γ = 100.0

Z	HWu	HWs	W.P	HSu	HSs	D.S	S.P
.100	47709	42942	.900	91909	83485	8424	.092
.200	47709	37698	.790	91909	73929	17980	.196
.300	47709	32143	674	91909	63469	28440	.309
.400	47709	26326	.552	91909	52269	39640	.431
.500	47709	20313	.426	91909	40499	51410	.559
.600	47709	17323	.363	91909	30810	61099	.665
.700	47709	16721	.350	91909	29843	62066	.675
.800	47709	16192	.339	91909	28993	62916	.685
.900	47709	15726	330	91909	28244	63665	.693
1.000	47709	15314	.321	91909	27583	64326	.700
1.100	47709	14949	.313	91909	26997	64913	.706

Table (B.14)summer and winter radiation on shaded and unshaded window with overhang for γ =110.0

Z	HWu	HWs	W.P	HSu	HSs	D.S	S.P
.100	39494	33883	858	86315	77054	9261	.107
.200	39494	27998	.709	86315	66715	19599	.227
.300	39494	23549	596	86315	55586	30729	.356
.400	39494	20129	.510	86315	44698	41617	.482
.500	39494	18008	.456	86315	35255	51060	.592
.600	39494	17323	.439	86315	30810	55504	.643
.700	39494	16721	.423	86315	29843	56471	.654
.800	39494	16192	.410	86315	28993	57321	.664
.900	39494	15726	398	86315	28244	58070	.673
1.000	39494	15314	.388	86315	27583	58732	.680
1.100	39494	14949	.379	86315	26997	59318	.687

Table (B.15)summer and winter radiation on shaded and unshaded window with overhang for $\gamma = 120.0$

Z	HWu	HWs	W.P	HSu	HSs	D.S	S.P
.100	30973	27101	875	78474	68378	10096	.129
.200	30973	23965	.765	78474	58243	20231	.258
.300	30973	20847	673	78474	48287	30187	.385
.400	30973	18788	.607	78474	39509	38965	.497
.500	30973	18008	.581	78474	32367	46107	.588
.600	30973	17323	.559	78474	30810	47664	.607
.700	30973	16721	.540	78474	29843	48631	.620
.800	30973	16192	523	78474	28993	49481	.631
.900	30973	15726	508	78474	28244	50230	.640
1.000	30973	15314	.494	78474	27583	50891	.649
1.100	30973	14949	.483	78474	26997	51477	.656

Table (B.16)summer and winter radiation on shaded and unshaded window with overhang for $\gamma = 130.0$

Z	HWu	HWs	W.P	HSu	HSs	D.S	S.P
.100	27365	24065	879	69759	60653	9106	.131
.200	27365	21655	.791	69759	51414	18345	.263
.300	27365	19674	719	69759	42760	26999	.387
.400	27365	18788	.687	69759	35187	34572	.496
.500	27365	18008	.658	69759	31911	37847	.543
.600	27365	17323	.633	69759	30810	38948	.558
.700	27365	16721	.611	69759	29843	39915	.572
.800	27365	16192	.592	69759	28993	40765	.584
.900	27365	15726	.575	69759	28244	41514	.595
1.000	27365	15314	.560	69759	27583	42176	.605
1.100	27365	14949	.546	69759	26997	42726	.613

Table (B.17)summer and winter radiation on shaded and unshaded window with overhang for $\gamma = 140.0$

Z	HWu	HWs	W.P	HSu	HSs	D.S	S.P
.100	25003	22480	899	62047	35881	8166	.132
.200	25003	20676	.827	62047	45235	16812	.271
.300	25003	19674	787	62047	37745	24302	.392
.400	25003	18788	.751	62047	33164	28883	.465
.500	25003	18008	.720	62047	31911	30136	.486
.600	25003	17323	.693	62047	30810	31237	.503
.700	25003	16721	.669	62047	29843	32204	.519
.800	25003	16192	.648	62047	28993	33054	.533
.900	25003	15726	.629	62047	28244	33803	.545
1.000	25003	15314	.612	62047	27583	34464	.555
1.100	25003	14949	.598	62047	26997	35051	.565

Table (B.18)summer and winter radiation on shaded and unshaded window with overhang for $\gamma = 150.0$

Z	HWu	HWs	W.P	HSu	HSs	D.S	S.P
.100	23357	21802	933	55666	47164	8502	.153
.200	23357	20676	.885	55666	39878	15788	.284
.300	23357	19674	.842	55666	34698	20968	.377
.400	23357	18788	.804	55666	33164	22502	.404
.500	23357	18008	.771	55666	31911	23755	.427
.600	23357	17323	.742	55666	30810	24856	.447
.700	23357	16721	.716	55666	29843	25832	.464
.800	23357	16192	.693	55666	28993	26673	.497
.900	23357	15726	.673	55666	28244	27422	.493
1.000	23357	15314	.656	55666	27583	28083	.504
1.100	23357	14949	.640	55666	26997	28669	.515

Table (B.19)summer and winter radiation on shaded and unshaded window with overhang for $\gamma = 160.0$

Z	HWu	HWs	W.P	HSu	HSs	D.S	S.P
.100	23058	21802	946	45932	47164	6583	.143
.200	23058	20676	.897	45932	39878	9736	.212
.300	23058	19674	.853	45932	34698	11345	.247
.400	23058	18788	.815	45932	33164	12768	.278
.500	23058	18008	.781	45932	31911	14021	.305
.600	23058	17323	.751	45932	30810	15121	.329
.700	23058	16721	.725	45932	29843	16088	.350
.800	23058	16192	.702	45932	28993	16939	.369
.900	23058	15726	.682	45932	28244	17687	.358
1.000	23058	15314	.664	45932	27583	18349	.399
1.100	23058	14949	.648	45932	26997	18935	.412

Table (B.20)summer and winter radiation on shaded and unshaded window with overhang for $\gamma \doteq 170.0$

Z	HWu	HWs	W.P	HSu	HSs	D.S	S.P
.100	23058	21802	946	40023	38005	2018	.050
.200	23058	20676	.897	40023	36196	3827	.096
.300	23058	19674	.853	40023	34587	5436	.136
.400	23058	18788	.815	40023	33164	6859	.171
.500	23058	18008	.781	40023	31911	8112	.203
.600	23058	17323	.751	40023	30810	9213	.230
.700	23058	16721	.725	40023	29843	10180	.254
.800	23058	16192	.702	40023	28993	11030	.276
.900	23058	15726	.682	40023	28244	11779	.294
1.000	23058	15314	.664	40023	27583	12440	.311
1.100	23058	14949	.648	40023	26997	13026	.325

.700	23058	16721	.725	40023	29843	10180	.254
.800	23058	16192	.702	40023	28993	11030	.276
.900	23058	15726	.682	40023	28244	11779	.294
1.000	23058	15314	.664	40023	27583	12440	.311
1.100	23058	14949	.648	40023	26997	13026	.325

Table B.22 : Monthly average daily radiation on vertical window with over hang for $\gamma = 0.0$ (South window).

Month	H_{S1} KJ/m^2	H_{S2} KJ/m^2	H_{S3} KJ/m^2	H_{S4} KJ/m^2
Jan	11056	9691	8378	7106
Feb	9132	7633	6200	4819
Mar	9703	7256	4899	3425
Apr	7299	4994	4546	4245
May	6574	5846	5400	5056
June	7042	6440	5973	5612
Jul	6869	6284	5830	5480
Aug	7485	5702	5297	4985
Sep	10352	6997	4429	4174
Oct	17117	13796	10494	7276
Nov	12778	11077	9431	7829
Dec	13630	12086	10586	9128

- H_{S1} : Total radiation on shading window with Z = 0.2
H_{S2} : Total radiation on shading window with Z = 0.4
H_{S3} : Total radiation on shading window with Z = 0.6
H_{S4} : Total radiation on shading window with Z = 0.8

Table B.23 : Monthly average daily radiation on vertical window with over hang for $\gamma=\pm 45$ (sw, SE windows).

Month	H_{S1} KJ/m^2	H_{S2} KJ/m^2	H_{S3} KJ/m^2	H_{S4} KJ/m^2
Jan	8916	7761	6752	5899
Feb	8192	7031	6058	5218
Mar	10540	8898	7427	5461
Apr	10419	8517	5971	4245
May	10706	7722	5400	5056
June	11022	7048	5973	5612
Jul	11300	7613	5830	5480
Aug	12160	9467	5673	4985
Sep	12868	10769	8462	5337
Oct	15992	13608	11622	9557
Nov	10477	9082	7871	6858
Dec	10662	9327	8140	7120

- H_{S1}, H_{S2}, H_{S3}, H_{S4} as in table (2.3)

Table B.24 : Monthly average daily radiation on vertical window with over hang for $\gamma=\pm90$ (E or west windows).

Month	H_{S1} KJ/m^2	H_{S2} KJ/m^2	H_{S3} KJ/m^2	H_{S4} KJ/m^2
Jan	5715	4560	3271	1947
Feb	6197	4902	3472	2346
Mar	9246	7114	4721	3425
Apr	10801	8160	5200	4245
May	12718	9397	5650	5056
June	14329	10411	5973	5612
Jul	14151	10314	5953	5480
Aug	13456	9936	5927	4985
Sep	11996	9035	5658	4174
Oct	12115	9246	5977	3683
Nov	6871	5432	3810	2246
Dec	6363	5070	3609	2035

ملخص

التصميم الأفضل لبعض أجهزة التظليل في الاردن

تم في هذه الرسالة تصميم أجهزة التظليل على النوافذ بطريقة بحيث تعمل على توفير الطاقة سواء في فصل الصيف وذلك بإحداث أكبر ظلال وخلال فصل الشتاء بحيث تقلل نسبة التظليل ومن شأن ذلك العمل على حفظ الطاقة وخاصة في الأردن. لقد تم حساب كمية الأشعة الساقطة على النافذة في حالة وجود جهاز التظليل وفي حالة عدم وجود جهاز التظليل وثم تم حساب كفاءة جهاز التظليل في الصيف والشتاء.

وتم رسم منحنيات الأداء لأجهزة التظليل التي تحتوي على كفاءة جهاز التظليل في الصيف وفي الشتاء معاً.

حيث تمت الحسابات لجميع الإتجاهات من الجنوب إلى الشمال وبالإعتماد على كمية الأشعة المقاسة تجريبياً لمدينة عمّان.

وأخيراً أدت النتائج من منحنيات الأداء التي تم رسمها أنه يمكن اختيار الأبعاد المناسبة لجهاز التظليل، مما يساعد على حفظ الطاقة سواء في فصل الصيف أو في فصل الشتاء.