CHAPTER 16

Aerial Surveying

16.1 Introduction

- Aerial survey is another type of survey wherein photographs are taken from air that depicts a part of earth's surface. Other terms that are used synonymously are **aerial photography, aerial photogrammetry.**
- The term aerial survey incorporates with in it two terms viz. the process of taking the photographs i.e. *photogrammetry* and the process of *photo interpretation*.
- In other words, 'photogrammetry' can be defined as the process of developing a map (mosaic or an assortment) by combining different photographs of the earth's surface.

16.2 Terrestrial Photograph and Terrestrial Photogrammetry

- It is also known as **ground photograph.**
- Here the instrument being used is photo-theodolite.
- Photo-theodolite is nothing but a conventional camera fitted on a tripod with the camera axis horizontal and a theodolite.
- It is very similar to plane table surveying and various ground features are shown in photographs. The features are located by intersection of line of sight from two or more stations.
- Similar to plane tabling, the plotting work is done in the field only.

16.3 Aerial Photograph and Aerial Photogrammetry

- Here also the same camera is used but the camera axis is vertical here.
- The camera is mounted on an aircraft. Aerial photography covers a large area as compared to terrestrial photography.
- Now a days, it has almost replaced the terrestrial photogrammetry due to the fact that here the pace of work and accuracy is more than the terrestrial photogrammetry.
- In aerial photogrammetry, the camera axis is kept parallel to the direction of gravity, camera being mounted on an aircraft and vertical photographs of the ground are taken. The aircraft flies along the parallel predetermined flight paths.

- A few prominent points are located on the ground to be surveyed that can be identified in an aerial photograph. These control points control the scale of plot.
- In order to have a constant scale in the various photographs being taken, the aircraft should fly along a horizontal path at the pre-decided altitude.
- The parallel paths that are required to be followed by the aircraft carrying the camera are called as **flight strips** that are planned well in advance of the commencement of aerial photography work.
- The photographs are required to be examined stereoscopically and for that overlap of photographs is a must. Thus the photographs are taken in such a manner that the successive photographs along a particular flight strip should overlap a part of preceding photograph also.
- It is desirable to have about 60% longitudinal overlap and 30% side overlap thereby covering the entire area to be surveyed.
- Every two consecutive photographs (constituting a pair) taken with adequate overlap forms a pair which is known as **stereo pair.** For the photographic map of the whole area, a number of stereo pairs are required.

NOTE: It is interesting to note that when a stereo pair is viewed through a stereoscope then the resulting picture seen is same as viewed by a camera on the aircraft.

- The most crucial aspect of aerial photography is the interpretation of aerial photographs. This needs the skill and past experience along with knowledge of Geology and other earth sciences.

Advantages of Aerial Surveying

(a) It is quite useful for developing small scale map of large area and large scale map of small area.

(b) It is beneficial for earth exploration purpose, planning and development of infrastructure like railways, highways, pipelines, zoning of areas, etc.

(c) With the advent of Geographical Information System (GIS), the importance of photogrammetry cannot be underestimated.

(d) The method of aerial photography offers the convenience and pace with which an area can be surveyed.

16.4 Aerial Photograph

- Aerial photograph is the photograph of an area taken from air with a camera mounted on an aircraft.
- This image of the ground that is being photographed gets formed on the focal plane of the camera's objective lens at which a sensitive film is placed.
- With the distribution of light and shade in a photograph along with certain other factors, the various items on the photograph can be identified.
- In a vertical photograph, it is required to keep the camera axis vertical i.e. parallel to the direction of gravity. But it is very difficult to maintain the optical axis of camera truly vertical. This gives rise to tilted photographs.
- Tilted Photograph: In a tilted photograph, the camera axis is *unintentionally* inclined to the vertical by an angle not exceeding 3°.
- Oblique Photograph: In an oblique photograph, the camera axis is inclined *intentionally* to the vertical and the resulting photograph is called as oblique photograph.
- A limiting case of oblique photograph is the **high-oblique photograph** which contains the horizon while in a **low-oblique photograph,** the photograph does not contain the horizon.

Table 16.1 *Difference between a Map and an Aerial Photograph*

S.No.	Map	Aerial Photograph
1.	It is an orthogonal projection.	It is a perspective projection.
2.	Selected details are shown.	A vast number of details are available.
3.	More clarity due to use of legends and other symbolic representations.	Less clarity due to no symbolic representations etc.
4.	It has a constant scale.	Here the scale differs due to variation of elevations.

16.5 Terminologies in Aerial Surveying

(a) Vertical Photograph

Fig. 16.1 shows a typical vertical photograph. Here *O′* is the principal point on the photograph with distance *LO′* is being equal to focal length (*f*) of the camera. The plane of photograph positive is at a distance *OL* from the camera lens. The shape and geometry of positive ***abcd*** is same as object *ABCD*.

(b) Scale of Photograph

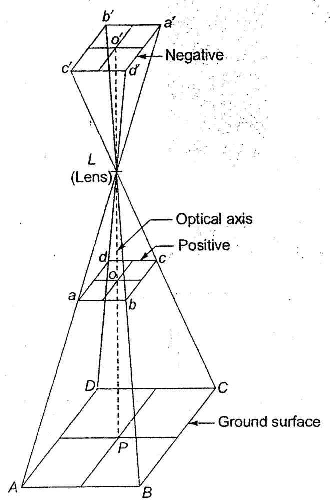


Fig. 16.1 *Vertical photograph*

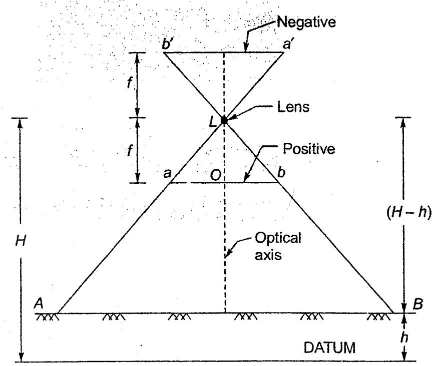


Fig. 16.2 *Scale of photograph*

The scale of photograph is defined as,

Scale of photograph = Photo distance / Ground distance

In **flat terrain photograph** as shown in **Fig. 16.2,**

Scale of photograph (S) = ab/AB

- **Flying height:** The elevation of camera lens above datum is called as flying height (H). Generally mean sea level (MSL) is taken as the datum.

In **Fig. 16.2,** $\Delta LAB \sim \Delta LaO$ and thus,

$$ab/AB = LO/LP = f/(H-h)$$

$$S = f/(H-h)$$

where f = Focal length of the camera

$H-h$ = Flying height above the ground

(c) Datum Scale

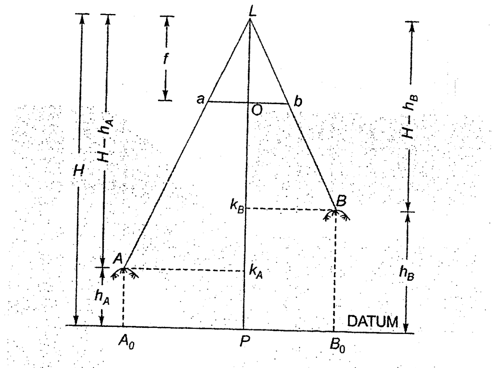


Fig. 16.3 *Datum scale*

It is that scale which will be effective over the entire photograph when all the ground points were projected vertically downwards on the datum.

From **Fig. 16.3,** Datum scale (S_d) = $aO/A_oP = LO/LP = f/H$

(d) Average Scale

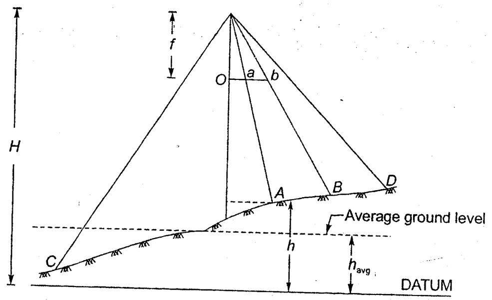


Fig. 16.4 *Average scale*

It is that scale which will be effective over the entire photograph if all the ground points were projected vertically upwards or downwards on a plane of average elevation of the ground terrain. As shown in **Fig. 16.4,** the average scale of the photograph is,

$$\text{Average scale } (S_{avg}) = f/(H-h_{avg})$$

where h_{avg} = Average elevation of points A and B on the ground

(e) Crab

Crab of a photograph is the angle between the flight line of the aircraft and the edges of the photograph in the direction of flight.

(f) Drift

It is the sideways (i.e. lateral) shift of the photograph since flight line does not remain straight on the predetermined flight due to various disturbances like wind etc.

16.6 Relief Displacement

Relief is the elevation of object above or below the datum. **Relief displacement** is the lateral displacement (also called as shift) in the position of image on the photograph of a ground object.

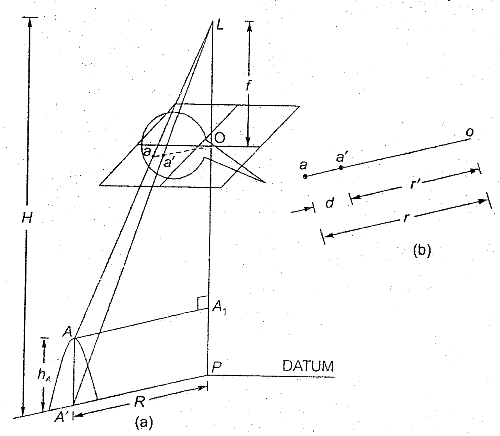


Fig. 16.5 *Relief displacement*

In **Fig. 16.5,** point A is above A' where A' is on datum. The plotted positions of points A and A' on photograph are **a** and **a'** respectively. The shift **aa'** is called as relief displacement.

Now $\Delta LOa \sim \Delta LA_1A$ and thus

$$AO/AA_1 = LO/LA_1$$

$$r/R = f/(H-h_A)$$

$$fR = r(H-h_A) \quad \text{...(16.1)}$$

Also $\Delta LOa' \sim \Delta LPA'$ and thus

$$Oa'/A_1A = LO/LP$$

$$r'/R = f/H$$

$$r'H = fR \quad \text{...(16.2)}$$

From (16.1) and (16.2)

$$R(H-h_A) = r'H$$

$$r - r' = rh_A/H$$

i.e. Relief displacement = rh/H

where h = Height of the object above datum

H = Flying height above datum

r = Radial distance of the image of the object top from point O

16.7 Area Covered by One Photograph

- Area covered by one photograph = (Length × Scale) × (Width × Scale)

16.7.1 Number of Photographs Required to Cover an Area

- When there is no overlap,

  No. of photographs required = Total area of ground / Area of one photograph

- When there is longitudinal and side overlaps, the following procedure is adopted :

  Let P_L = Longitudinal overlap

  P_w = Side overlap

  L = Length of ground being surveyed

  W = Width of ground being surveyed

  l = Length of photograph in the flight direction

  w = Width of photograph in the direction normal to flight direction

  S = Scale of the photograph

  Thus,

  $$L = (1 - P_L)Sl$$

  $$W = (1 - P_w)\,Sw$$

  Thus ground area covered by each photograph is,

  $$a = LW = (1 - P_L)(1 - P_w)(Sl)(Sw)$$

  $$a = S^2lw(1 - P_L)(1 - P_w)$$

  Number of photographs required to cover the area, $N = A/a$

- When ground area is given ($A = L_1B_1$), the number of photographs required is given by number of photographs in each strip and the number of strips.

  Let N_1 = No. of photographs in each strip

  N_2 = No. of strips

  Thus,

  Net length covered by each photograph, $L = (1 - P_L)Sl$

  Similarly, net width covered by each photograph $W = (1 - P_w)Sw$

  So, total no. of photographs required = $N_1 \times N_2$

16.8 Exposure Interval

Let V = Ground speed of aircraft (in km/hr)

L = Ground distance covered along the flight line (in km)

The time interval between the exposures is,

$$t = L/V \text{ (in hr)}$$

$$= 3600\, L/V \text{ (in sec)}$$

16.9 Air Base

The distance covered by an aircraft between any two successive exposures.

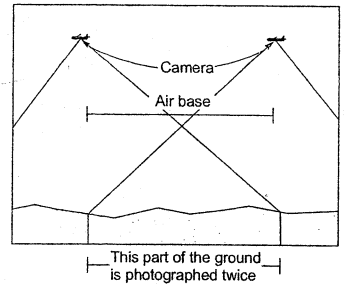


Fig. 16.6 *Air Base*

Illustrative Examples

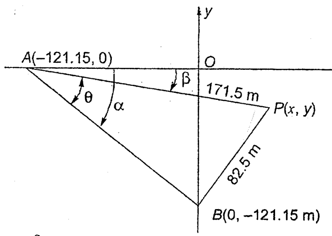
Example 16.1 The co-ordinates of two points A and B are as follows:

	Abcissa (m)	Ordinate (m)
A	−121.15	0
B	0	−121.15

Find the co-ordinates of point P if distances AP and BP are 171.5 m and 82.5 m respectively.

Solution:

Let co-ordinates of P be $P(x, y)$



$$AB = \sqrt{OA^2 + OB^2}$$

$$= \sqrt{(121.15)^2 + (121.15)^2}$$

$$= 171.33 \text{ mm}$$

$$\cos\theta = \frac{AP^2 + AB^2 - BP^2}{2(AP)(AB)}$$

$$= \frac{(171.5)^2 + (171.33)^2 - (82.5)^2}{(171.5)(171.33)} = 0.88418$$

$\therefore$ $\theta = 27.85°$

$$\tan\alpha = \frac{121.15}{121.15} = 1$$

$\therefore$ $\alpha = 45°$

$\therefore$ $\beta = \alpha - \theta = 45° - 27.85° = 17.15°$

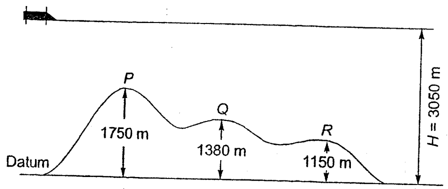
$\therefore$ $x = AP\cos\beta - A° = 171.5 \cos 17.15° - 121.15 = 42.72$ m

$y = -AP\sin\beta = -171.5 \sin 17.15° = -50.57$ m

$\therefore$ Co-ordinate of pare $P(42.72, -50.57)$

Example 16.2 There are three points P, Q and R which are 1750 m, 1380 m and 1150 m above datum. The flying height of camera is 3050 m above datum. The focal length of the camera is 125 mm Determine different scales of the photograph

Solution:



Scale of photograph at P, $s_P = \dfrac{f}{H-h_P} = \dfrac{0.125}{3050-1750} = 1 \text{ in } 10400$

Scale of photograph at Q, $s_Q = \dfrac{f}{H-h_Q} = \dfrac{0.125}{3050-1380} = 1 \text{ in } 13360$

Scale of photograph at R, $S_R = \dfrac{f}{H-h_R} = \dfrac{0.125}{3050-1150} = 1 \text{ in } 15200$

Average elevation of terrian points P, Q and R,

$$h_{avg} = \frac{1750+1380+1150}{3} = 1426.67 \text{ m}$$

∴ Average scale of photograph,

$$s_{avg} = \frac{0.125}{3050-1426.67} = 1 \text{ in } 12986.64$$

Example 16.3 In a map points are plotted at a scale of 1 in 15500. The length of highway on the map is 150 mm. If photodistance of the highway is 215 mm then what is the scale of the photograph?

Solution:

$$\text{Scale of map} = \frac{\text{Map distance}}{\text{Ground distance}} \quad \text{...(i)}$$

$$\text{Scale of photograph} = \frac{\text{Photo distance}}{\text{Ground distance}} \quad \text{...(ii)}$$

From eq. (i) and (ii)

$$\frac{\text{Scale of map}}{\text{Scale of photograph}} = \frac{\text{Map of distance}}{\text{Photo distance}}$$

$$\Rightarrow \quad \text{Scale of photograph} = \frac{\text{Photo distance}}{\text{Map distance}} \times \text{Scale of map}$$

$$= \frac{215}{150} \times \frac{1}{15500}$$

$= 1 \text{ in } 10813.95$

$\simeq 1 \text{ in } 10814$

Example 16.4 Find the number of photograph required to cover an area of 750 km^2 is scale of the photograph is 1 in 15600. The size of photograph is 6″ × 4″. The longitudinal and side overlaps are 55% and 25% respectively.

Solution:

Area covered on ground by one photograph

$$= (1-p)(1-s)(lw)\frac{1}{s^2}$$

$$= (1-0.55)(1-0.25)(6\times0.0254\times4\times0.0254)\times\frac{1}{s^2}$$

$$= \frac{5.2258\times10^{-3}\times(15600)^2}{1}$$

$= 1271749.715 \text{ m}^2 = 1.2717 \text{ km}^2$

∴ Number of photograph required

$$= \frac{750}{1.2717} = 589.76 \simeq 590 \text{ (say)}$$

Example 16.5 A line PQ measures 12 cm on a photograph taken with a camera of focal length 22.5 cm. The same line measures 4 cm on a map drawn to scale of 1 : 35000. If average attitude is 300 m then what is the flying height of the aircraft?

Solution:

$$\frac{\text{Photo scale}}{\text{Map scale}} = \frac{\text{Photo distance of line } PQ}{\text{Map distance of line } PQ}$$

$$\Rightarrow \quad \frac{S}{1/35000} = \frac{12}{4}$$

$$\Rightarrow \quad S = \frac{3}{35000}$$

Now, photoscale, $S = \dfrac{f}{H-h}$

$$\Rightarrow \quad \frac{3}{35000} = \frac{0.225}{H-300}$$

$\Rightarrow \quad H = 2925 \text{ m} = 2.925 \text{ km}$

Example 16.6 A 2280 m line lying at an elevation of 425 m measures 11.5 cm on a vertical photograph. The focal length of the camera used is 18.5 cm. Find the scale of photograph for a terrain having an elevation of 1050 m.

Solution:

$$\text{Scale at 425 m elevation} = \frac{11.5}{2280} = \frac{f}{H-h}$$

$$\Rightarrow \quad \frac{11.5}{2280} = \frac{18.5}{H-425}$$

$\Rightarrow \quad H = 4092.826 \text{ m}$

$$\text{Scale at 1050 m elevation} = \frac{f}{H-h} = \frac{18.5 \text{ cm}}{(4092.826-1050)\text{m}}$$

$$= \frac{1 \text{ cm}}{164.477 \text{ m}} = \frac{1 \text{ cm}}{16447.7 \text{ cm}}$$

Thus scale is 1 : 16447.7

Example 16.7 Two points A and B have elevations of 750 m and 325 m respectively, above datum. These points are photographed with a camera of focal length 22.7 cm at a flying altitude of 2850 m above datum. The photographic co-ordinates are as follows :

Point	Photographic co-ordinates	
	x(cm)	y(cm)
a	+ 4.65	+ 3.95
b	− 3.45	+ 7.78

What is the length of ground the AB?

Solution:

$$\because \quad \frac{x}{X} = \frac{f}{H-h}$$

$$X_a = \left(\frac{H-h_a}{f}\right)x_a = \left(\frac{2850-750}{22.7}\right)4.65 = 430.18 \text{ m}$$

Similarly

$$X_b = \left(\frac{H-h_b}{f}\right)x_b = \left(\frac{2850-325}{22.7}\right)(-3.45) = -383.76 \text{ m}$$

$$Y_a = \left(\frac{H-h_a}{f}\right)y_a = \left(\frac{2850-750}{22.7}\right)3.95 = 365.42 \text{ m}$$

$$Y_b = \left(\frac{H-h_b}{f}\right)y_b = \left(\frac{2850-325}{22.7}\right)7.78 = 865.40 \text{ m}$$

$$\therefore \quad AB = \sqrt{(X_a - X_b)^2 + (Y_a - Y_b)^2}$$

$$= \sqrt{(430.18+383.76)^2 + (365.42-865.40)^2} = 955.24 \text{ m}$$

Example 16.8 A scale of an aerial photograph 30 cm × 30 cm is 1 km = 10 m. Find the number of photographs required to cover an area of 25 km × 20 km if longitudinal overlap is 60% and side overlap is 25% .

Solution:

$$\text{Number of photographs per strip} = \frac{\text{Length of area}}{(1-P_L)sl} + 1$$

$$= \frac{25 \times 1000}{(1-0.6)100(30)} + 1 = 21.83 = 22$$

$$\text{Number of strips} = \frac{\text{width of area}}{(1-P_w)S_w} + 1 = \frac{20 \times 1000}{(1-0.25)100 \times 30} + 1 = 9.89 = 10$$

$$\therefore \text{Total number of photographs required} = 22 \times 10 = 220 \text{ nos.}$$

Example 16.9 Compare the scales of photograph for an area and the strip width by two cameras A and B flying at the same height.

	Camera A	Camera B
Photograph size	180 mm × 180 mm	230 mm × 230 mm
Focal length	228 mm	145 mm

How many photographs will be taken by camera A in covering a strip of 20 km length flying at a height of 1525 m? The longitudinal overlap of photographs is 55%.

Solution:

$$\text{Scale of photograph} = \frac{H}{f}$$

$$\therefore \quad \frac{\text{Scale of photograph of camera } A}{\text{Scale of photograph by camera } B} = \frac{f_B}{f_A} \qquad (\because H_A = H_B)$$

$$= \frac{145}{228}$$

Now length of strip, L = 20 km = 20000 m

longitudinal overlap, P_L = 55% = 0.55

Length of photograph by camera A, l = 180 mm = 18 cm = 0.18 m

Focal length of camera A, f_A = 228 m

$$\text{Scale of photograph by camera } A,\ S = \frac{H}{f_A} = \frac{1525}{0.228}$$

= 1.6688.6 = i.e. 1 cm = 66.88 m

$$\therefore \quad \text{No. of photograph to cover 20 km length} = \frac{L}{(1-P_L)Sl} + 1$$

$$= \frac{20000}{(1-0.55)66.88 \times 18} + 1 = 38 \text{ nos.}$$

Example 16.10 A telecommunication tower is 130 m high and it appears at principal point on the vertical photograph was taken shortly after the first photograph. In the next photograph, the base of the tower appears on X-axis distant 95.5 mm left of principle point. The format of photograph is 180 mm x 180 mm. The aircraft was flying at 880 m and the focal length of the camera is 135 mm. What is the distance of top tower from Y axis on the next photograph and the percentage overlap?

Solution:

Let P_1 and P_2 be the two consecutive photographs

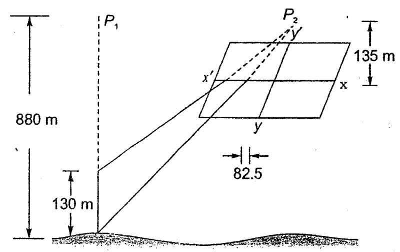
r_0 = 95.5 mm

$H - h_f$ = 880 m

h_2 = 130 m

f = 135 m

$$\text{Scale of photograph, } S = \frac{f}{H-h_1} = \frac{r_0}{R}$$



$\therefore$ Ground distance, $R = \frac{r_0(H-h_1)}{f} = \frac{\left(\frac{95.5}{1000}\right)880}{0.135} = 622.52$

Radial distance of source top, $r_2 = \frac{R_f}{(H-h_2)} = \frac{622.52 \times 0.135}{880-130} = 0.11205 \text{ m} = 112.05 \text{ mm}$

Size of photograph = 180 mm × 180 mm

Ground distance covered between the two photographs, $R = 622.52$ m

$\therefore$ Scale $= \frac{f}{H-h_1} = \frac{0.135}{880} = 1:6518$ or 1 cm = 65.18 m

Length of photograph, l = 180 mm = 18 cm

$$\therefore \quad R = (1-P_L)Sl$$

$$\Rightarrow \quad 622.52 = (1-P_L)\,65.18(18)$$

$$\Rightarrow \quad P_L = 0.4694 \text{ or } 46.94\%$$

Example 16.11 An area of size 180 km × 210 km is to be surveyed by photogrammetry. Determine the number of photographs required to cover the area.

Given

Format of photograph	=	230 mm × 230 mm
Scale of photograph	=	1:28000
Average terrain elevation	=	350 m
Longitudinal overlap	=	60%
Side overlap	=	30%
Ground speed of aircraft	=	310 km/hr
Focal length of camera	=	220 mm

Solution:

$$S = \frac{f}{H}$$

$$\Rightarrow \quad \frac{1}{28000} = \frac{0.22}{H}$$

$$\Rightarrow \quad H = 6160,$$

Ground spacing of flight lines, W = $(1-P_W)\,S_W$

$= (1-0.3)\,280 \times 23 = 4508$ m

No. of the lines required, $N_2 = \frac{180 \times 1000}{4508} + 1 = 41$

Actual spacing of flight lines $= \frac{180 \times 1000}{41} = 4390.24$ m

Ground distance covered, $L = (1-P_L)Sl = (1-0.6)\,280(23) = 2576$ m

$\therefore$ Exposure internal $= \frac{2576}{\left(310 \times \frac{1000}{3600}\right)} = 29.9 = 2574.72$ m

No. of photographs per flight, $N_1 = \frac{210 \times 1000}{2574.72} + 1 = 83$

$\therefore$ Total number of photographs $= N_1 \times N_2 = 83 \times 41 = 3403$ Nos

Example 16.12 A flight mission is to be planned for an area of 14 km × 8 km size. The ground speed of the aircraft is 220 km/hr. The aircraft is fitted with a camera of focal length 20 cm. The mean scale is 1 : 13500. Average ground elevation is 370 m. The format of photograph is 230 mm × 230 mm. Longitudinal and side overlap are 60% and 30% respectively.

Solution:

$$S = \frac{f}{H-h}$$

$$\Rightarrow \quad \frac{1}{13500} = \frac{0.2}{H-370}$$

$$\Rightarrow \quad H = 3070 \text{ m}$$

Ground coverage of photograph $= \frac{23}{100} \times 13500 = 3105$ m

Effective longitudinal coverage = 0.4 × 31.05 = 1242 m = 1.242 km

Effective sideway coverage = 0.7 × 3105 = 2173.5 m = 2.1735 km

Exposure time $= \frac{1242}{\left(220 \times \frac{1000}{3600}\right)} = 20.32$ sec

No. of strips $= \frac{8 \times 1000}{2173.5} = 3.68 \simeq 4$

No. of photographs for strip $= \frac{14000}{1242} + 1 = 12.27 \simeq 13$ nos

Objective Brain Teasers

1. Aerial photographs are:
   (a) Isometric projections
   (b) Orthographic projections
   (c) Normal projections
   (d) Perspective projections

2. In a vertical photograph, relief displacement is always radial from the
   (a) Zenith point (b) Nadir point
   (c) Principal point (d) Isocenter

3. The point of intersection of x and y axes of an aerial photograph gives
   (a) Principal point (b) Zenith point
   (c) Nadir point (d) None of these

4. On a flat terrain with varying flying height, the scale of vertical photograph will be
   (a) Uniform
   (b) Uniform if tilt is not there
   (c) Non-uniform
   (d) Non-uniform if tilt is not there

5. If net length covered by each photograph is 1.5 km and length of the strip is 18 km, then number of photographs required is:
   (a) 13 (b) 12
   (c) 14 (d) 15

6. In an aerial photographic survey, the exposure interval is 3 seconds to cover a ground distance of 150 m. The ground speed of the aircraft (in km/hr) is:
   (a) 18 (b) 1.8
   (c) 180 (d) 1800

7. A vertical photograph was taken at an altitude of 2 km above MSL. The focal length of the camera is 20 m. The scale of the photograph for a terrain lying at an elevation of 300 m is:
(a) 1:100 (b) 1:85
(c) 1:15 (d) 1:50

8. The focal length of an aerial camera is 20 cm and the exposure station was 3000 m above the MSL (taken as datum). The scale of the photograph is:
(a) 1 cm =300 m (b) 1 cm = 150 m
(c) 1:300 (d) 1:150

9. The elevations of objects on an aerial photograph can be measured due to:
(a) Stereoscopic fusion
(b) Drift
(c) Tilt
(d) All of these

10. The vertical photographs do not represent the true plan of ground due to:
(a) Ground relief (b) Tilt
(c) Drift (d) Overlap

ANSWERS

1. (d)	2. (c)	3. (a)	4. (c)	5. (a)
6. (c)	7. (b)	8. (b)	9. (a)	10. (a)

Student's Assignments

Ex.1 A line 2445 m long located at an elevation of 489 m measures 11.5 cm on a vertical photograph. The focal length of the camera used for this purpose is 18 cm. Determine the scale of the photograph for an area having an elevation of 130 m.

Ans. 1 : 16477.55

Ex.2 Two points *P* and *Q* having elevations of 600 m and 225 m respectively above datum, appear on a vertical photograph. The focal length of the camera used is 230 mm and is flying at an altitude of 2985 m above datum. The corresponding photographic co-ordinates are as given below:

Point	Photographic co-ordinate (cm)	
	x	*y*
a	+4.650	+3.540
b	–2.365	–6.595

Determine the ground length of the line *AB*.

Ans. 1388.82 m

Ex.3 The distance from principal point to a point on image is 8.25 cm. The elevation of object above datum is 250 m. If focal length of the camera is 265 mm and datum scale is 1 : 9500 then what is the relief displacement?

Ans. 0.91 cm

Ex.1 The scale of an aerial photograph 30 cm × 30 cm size is 1 km = 20 m. What is the number of photographs required to cover an area of 25 km × 22 km, if longitudinal overlap is 60% and side overlap is 30%?

Ans. 946 nos.