B). CALCULATIONS EXECUTED BY THE COMPUTER

CALCULATION METHODS FOR CHAIRLIFTS

- Calculation of the line
- Calculation relating to the cable and the terminal stations
- Calculations of the footings and line towers.

Units used: MKSA system and derivations, i.e.

- Dimensions: in meters: m

  or in centimeters: cm

  or in millimeters: mm
- Weights: in kilograms: kg
- Time: in seconds: s
- Forces: in decanewtons: daN = 10 Newtons

B) CALCULATION METHODS

1) SPEEDS AND CAPACITIES

1.1 SPEEDS

N = Speed of motor in rpm
D = Diameter of drive sheave
R = Reduction ratio of main gearbox
r = Reduction ratio of auxiliary input, evac input, v-belts or other connection to main gearbox input

$$\text{Cable Speed} = \frac{N}{Rxr} \times \frac{3.14D}{60}$$

1.2 OPERATING CAPACITY

Let e = spacing between chairs
n = capacity of chair (persons)

We have:

- Capacity

$$Q = \frac{3600 \times V}{e} \times n$$

2. DISTRIBUTED LOADS

2.1 Line with chairs empty

$$Pv = \frac{\text{weight of chair}}{e} + \text{weight of cable (daN/m)}$$

2.2 Line loaded at 100%

$$PC = PV + \frac{n \times \text{weight of skier}}{e} \text{(daN/m)}$$

2.3 Line loaded at p %

$$Pn = PV + \frac{n \times \text{weight of skier}}{e} \times \frac{P}{100}) \quad \text{(daN/m)}$$

2.4 Line without chairs

$$P = \text{weight of cable (daN/m)}$$

3. LINE CALCULATION TABLES

3.1 Different tables possible

According to the loading conditions possible for each lift we have on the print-out several of the following tables:

- uphill side loaded at 100%
  downhill side loaded at 100%
- uphill side loaded at 100%
  chairs empty on downhill side
- chairs empty on uphill side
  downhill side loaded at 100%
- chairs empty on uphill and downhill sides
- cable empty on uphill and downhill sides

3.1 Different tables possible cont.

- uphill side loaded at 100%
  downhill side loaded at N%

- uphill side loaded at N%
  downhill side loaded at 100%

- chairs empty on uphill side
  downhill side loaded at N%

- uphill side loaded at 100 - N%
  downhill side loaded at N%

Recapitulative values include worst case results of all loading conditions considered. This table also checks compression towers with a 33% overload on the line and support towers (under the straight line) with a 50% overtension and no load on the adjacent spans.

3.2 Definition of table headings

At the top of the table:

Definition of the loading condition considered with the weights of the corresponding distributed loads.

To: tension exerted by the tension system

In the case of a drive tension system
it corresponds with T + t

T = tension of cable on incoming side of drive B.W.
t = tension of cable on outgoing side of drive B.W.

The tables are divided in three sections:

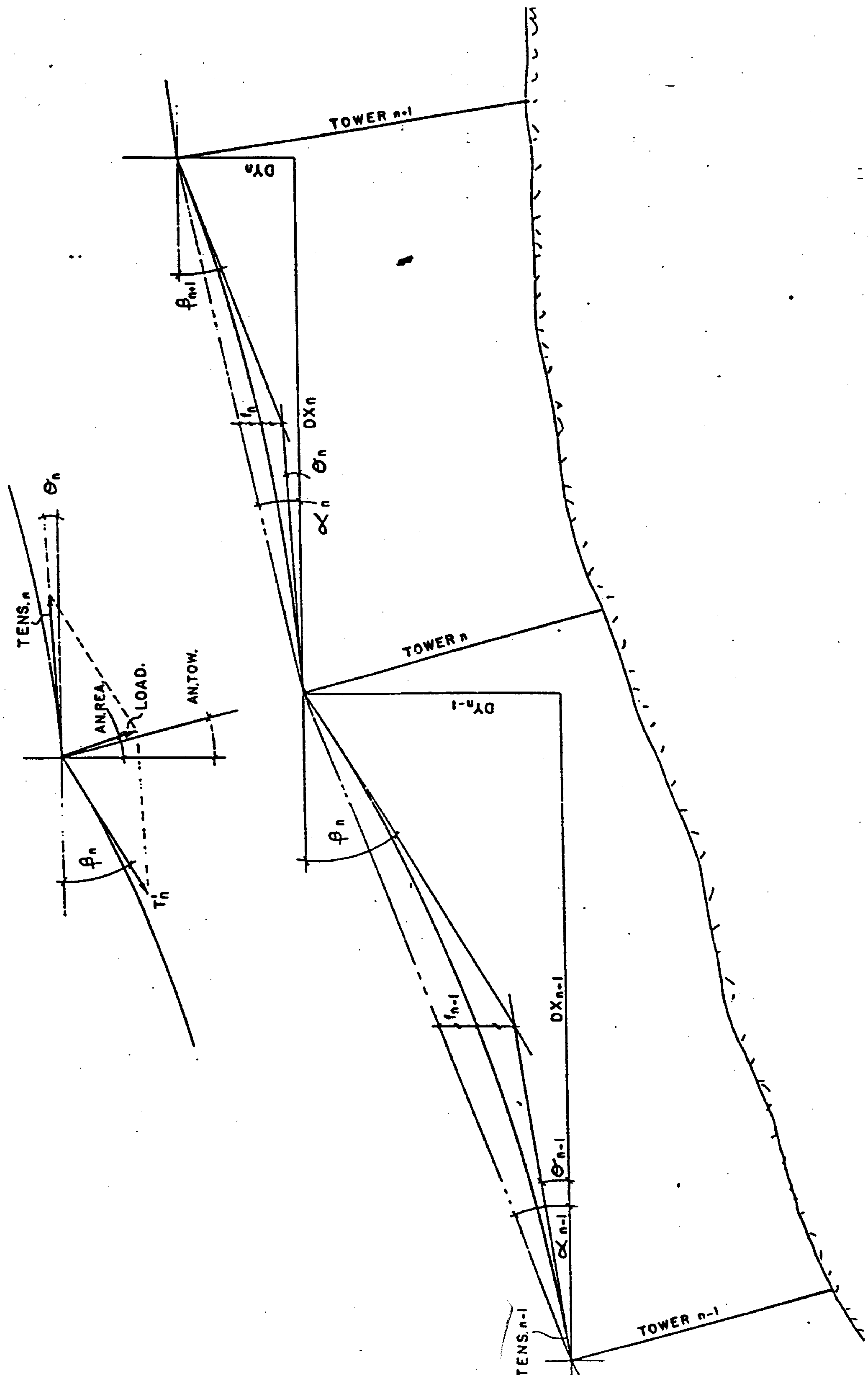
- the geometry of the line
- headings concerning the spans
- headings concerning the towers

Geometry of the line

NR: number defining the support
Dx: horizontal span uphill of NR
Dy: vertical difference uphill of NR

Heading concerning the spans

SAG: calculated at middle of span
TGT.: tangent θ
TGB.: tangent β
TENS.: tension at exit from rocker


TOWER n+1
DYn
βn+1
ln
DXn
θn
αn
TOWER n
DYn-1
βn
ln-1
DXn-1
θn-1
αn-1
TOWER n-1
TENS.n-1
TENS.n
θn
AN.REA.
LOAD.
AN.TOW.
βn
T'n

3.2 Definition of table headings cont.

Heading concerning the towers

LOAD.: reaction of the cable on the equipment
NSHE.: number of sheaves composing the equipment
AN.REA.: angle made by the reaction with the verticle
AN.TOW.: angle made by the tower with the verticle
2AL.O: maximum allowable deflection per sheave

3.3 Determination of the tensions and reactions on the rockers.

The formula used in the calculations of the cable are those accepted for the calculation of cable transporters in general, where the catenary is assimilated to a parabolic arc.

a) Calculation of Tension

The computer calculates the tensions along the line by an interative process. The effects of friction are added at each tower.

Example: $P\ell$ = line load (daN/m)
incoming tension at tower $T'n = TENS_{n-1} + (DY_{n-1} \times P\ell)$
estimate of outgoing tension $TENS_n = T'n$
load and friction are calculated $FF = LOAD \times .025$
friction force is added to tension $TENS_n = T'n + FF$

A new load and friction force are calculated and the process is repeated until an accurate friction force is achieved.

b) Calculation of LOAD

$$SAG = f_{n-1} = \frac{P(DX_{n-1})^2}{8\,T_A\,\cos^2(\alpha_{n-1})} \qquad \text{where } T_A = \frac{TENS_{n-1} + T'n}{2}$$

$$TGT_n = \tan\theta n = \frac{DY_n - 4f_n}{DX_n}$$

$$TGB_n = \tan\beta n = \frac{DY_{n-1} + 4f_{n-1}}{DX_{n-1}}$$

$$LOAD = \sqrt{(TENS_n \cos\theta_n - T'_n\cos\beta_n)^2 + (TENS_n \sin\theta_n - T'_n\sin\beta_n)^2}$$

3.3 Determination of the tensions and reactions on the rockers cont.

AN.REA. = angle of the reaction with the vertical (%)

$$AN.REA. = \frac{(\overset{OUT}{TENS_n}\cos\overset{OUT}{\theta_n} - \overset{IN}{T'_n}\cos\overset{IN}{\beta_n})}{(\underset{IN}{T'_n}\sin\underset{IN}{\beta_n} - \underset{OUT}{TENS_n}\sin\underset{OUT}{\theta_n})}$$

c). Sheaves

NSHE. = number of sheaves determined by the maximum allowable load per sheave.
G/SHE. = the deflection per sheave of the cable, given in radians = $\dfrac{(\beta_n - \theta_n)}{NSHE.} \times \dfrac{\pi}{180}$

d). Towers

AN.TOW. = angle of the tower to the vertical, this value is input into the computer.

e). 2AL.O = requirement by Poma limiting the angle of deflection per sheave according to the tension of the tower. The maximum allowable is 2AL.O = .078

4. TABLE OF VALUES RELATING TO THE CABLE AND TERMINAL STATIONS

This table is situated in the printout after the recapitulative values.

4.1 Cable and Tension System

The total length of the cable is calculated for the fully loaded case and the case of an empty lift. The difference between these cases, divided by two gives the carriage travel.

The tension may be set in the computer input or a maximum allowable tension in the cable is set and the computer will calculate the tension of the tension system.

4.2 Adherence

A limit value for adherence is set at $T/t = 1.9$ to prevent slippage of the cable on the drive sheave.

The exploitation maximum value is achieved with a full uphill and empty downhill case, this value must be less than 1.9. Braking and starting maximum values are determined using the inertias of the system and the acceleration.

4.3 Start-Up

In this case the inertia of the system is considered in achieving full speed in a required time interval. Since friction is usually a little higher when a system begins from a dead stop we increase the friction in this case.

In the normal case a value of $(T - t)$ is calculated using a line friction factor of 0.025. For start-up we use a line friction factor of .035.

4.4 Reducer Output Torque

This value is also calculated using a line friction of .035 giving a maximum.

$$M_{max} = (T - t)_{.035} \times \frac{D}{2}$$

D = diameter of drive bullwheel

NOT PART OF EQUATION.

4.5 Electric Motor and I.C. Engine

The maximum power required from the motor is:

$$P_{max} = \frac{(T - t) \times V}{73.58 \times \eta} \quad \text{(H.P.)}$$

V = speed (m/s)
η = efficiency
H.P. = $73.58 \ \frac{daNm}{s}$

The speed and torque of the motor are determined by the ratio of the transmission system.

$$V_{motor} = \frac{V \times 60}{\pi D} \times R \times r \quad \text{(r.p.m.)}$$

R = gearbox ration
r = V-belt ratio
(or secondary gearbox)

$$\text{Starting torque} = \frac{(T - t)_{.035} \times D/2}{R \times r \times \eta} \quad \text{(daN.m)}$$

4.6 Braking

a). Worst case conditions for braking

i). lift running full speed
ii). uphill side empty, downhill side full

b). All of the forces resisting braking are resolved into a single tangential force acting on the drive bullwheel (Fb).

Pe	= load of empty line	(daN/m)
Pf	= load of full line	(daN/m)
L	= length of line	(m)
γ	= deceleration of line	(m/s^2)
g	= acceleration of gravity	(m/s^2)
J	= rotational inertia of transmission system (taken at shaft of electric motor)	($kg\ m^2$)
j	= rotational inertia of line sheaves	($kg.m^2$)
d	= diameter of line sheaves	(m)
α	= rotational deceleration	(rad/s^2)
N	= number of line sheaves	

$$F_b = F_a + F_t + F_J + F_j$$

F_a = force due to deceleration of cable, chairs and passengers

$$F_a = \text{mass x deceleration} = \frac{(Pe + Pf) \times L}{g} \times \gamma \qquad \text{(daN)}$$

F_t = (T − t)(daN) for loading case uphill empty/downhill full

F_J = force due to inertia of the transmission system

$$F_J = \frac{J\alpha}{D/2} \times R \times r \times 10 = \frac{J\ \gamma}{(D/2)^2} \times R \times r = \frac{.4J\gamma Rr}{D^2} \qquad \text{(daN)}$$

$$\frac{D}{2}\alpha = \gamma$$

F_j = force due to the inertia of the line sheaves

$$F_j = \frac{j\alpha}{d/2} = \frac{j\ \gamma}{(d/2)^2} = \frac{.4j\gamma}{d^2}N \qquad \text{(daN)}$$

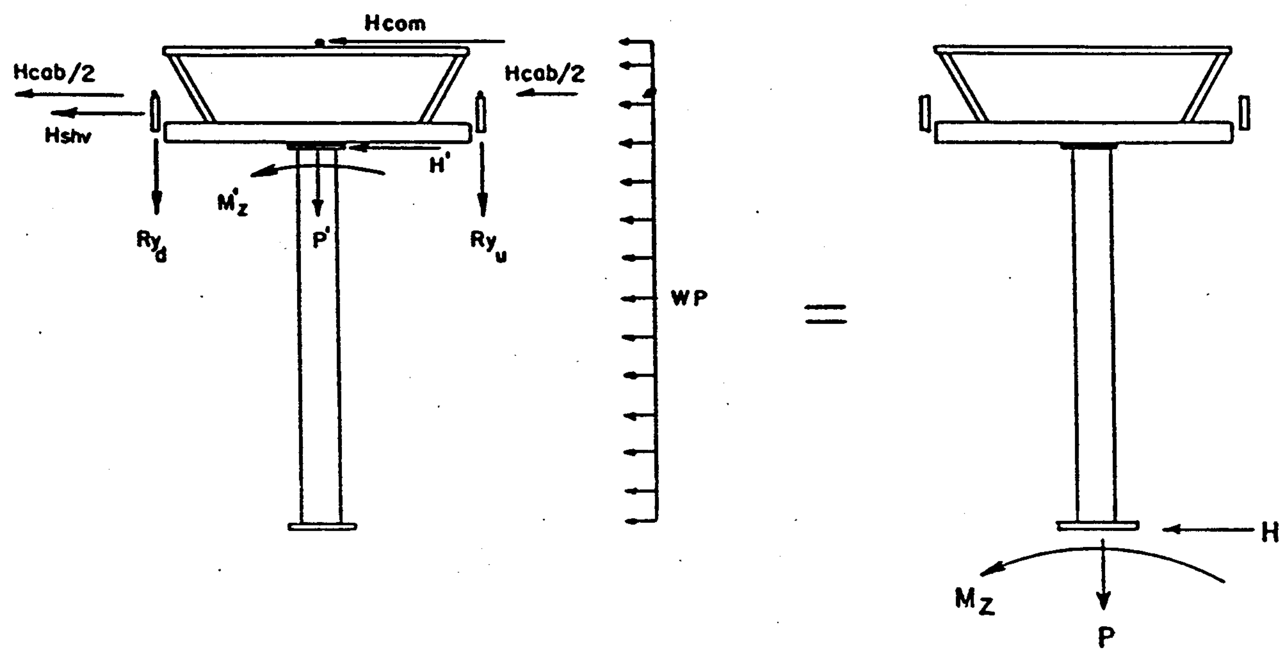
c). Braking torque

i). braking torque at the output shaft of the gearbox = M_b

$$M_b = F_b \times D/2 \qquad \text{(daN.m)}$$

5.1 Method of Calculation cont.

P' = sum of reactions and weights acting along the axis of the tower and applied at the connection between the tube and the x arm.

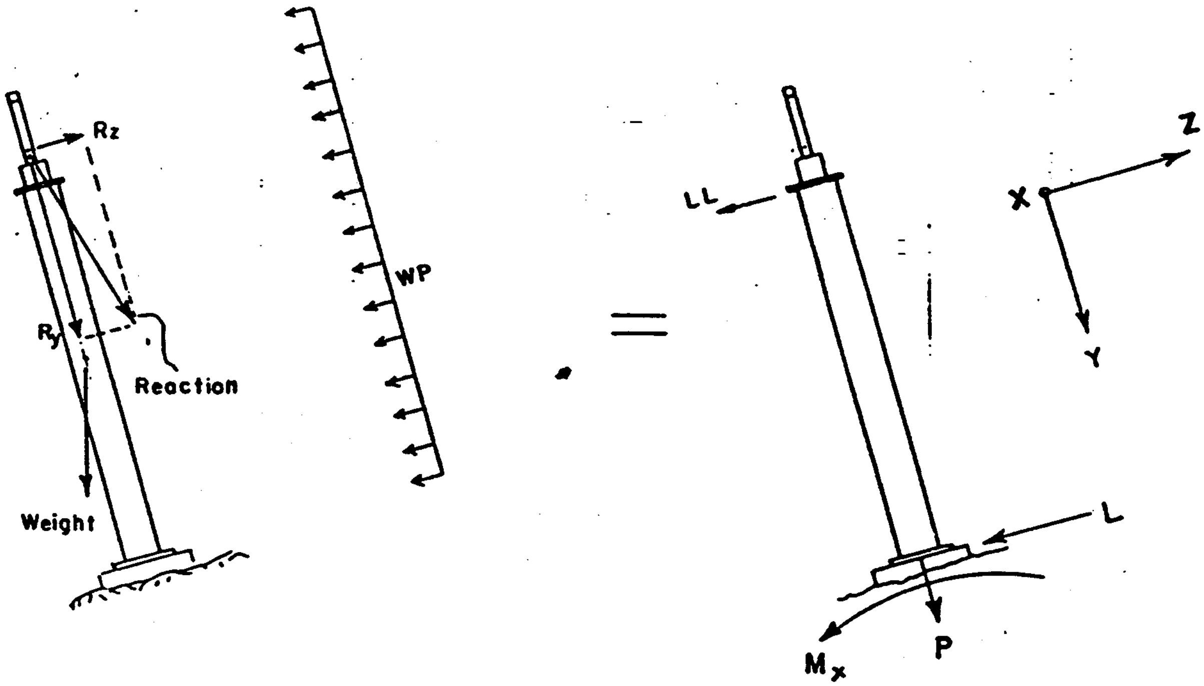


These forces ($M'z$, H', P') are combined with the wind force acting on the tower tube (across the line) and the weight of the tower tube to give resultant forces acting on the foundation.

Mz = moment across the line
H = horizontal force across the line
P = vertical force applied along the axis of the tower

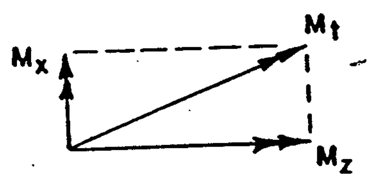
This maximum wind pressure is also considered to act along the line, resulting in an additional safety factor in the moment calculation.

Rz = resultant of reactions and weight of sheaves and crossarm in the z direction
LL = force along the line causes a moment (Mx). LL is the equivalent force applied to the tower at the top of the tube to cause this moment (Mx). When this force is too high we adjust the tower inclination to reduce the value of LL. This value is shown on the computer print-out as longitudinal load.



L = resultant of forces and weights in the z direction
Mx = resulting moment from combination of weights and forces applied to the tower in the z direction. Note that Mx = LL x length of tube
P = vertical force applied along the axis of the tower resulting from the reaction and the weight

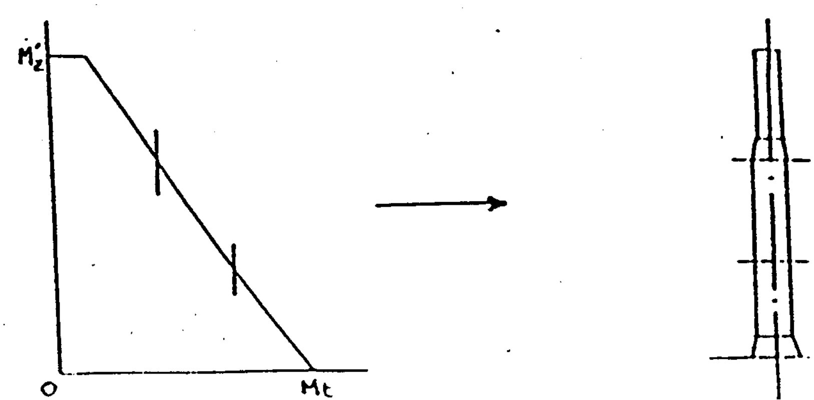
For the calculation of the moments in the towers and the overturning of the foundation M_T is used:



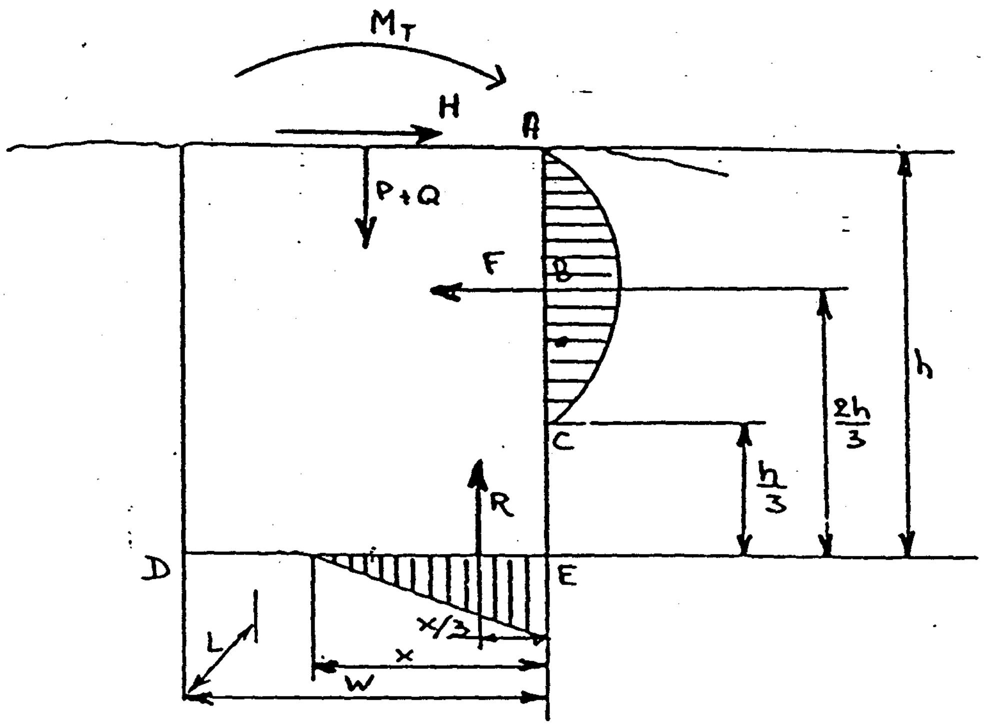
$$M_t = \sqrt{M_x^2 + M_z^2}$$

5.2 Choice of Tube Elements

We have at each point on the beam the bending moment and the normal stress. The programme reviews the various types of POMA standard tubes and determines the lengths of the elements in such manner that the normal prescribed stress does not exceed the allowable level, taking into account, if necessary, a possibility of buckling.



6/ CALCULATION OF THE FOOTINGS



P = vertical reaction from tower
H = horizontal reaction from tower x1.5
M_T = moment reaction from tower x1.5

Q = weight of concrete

$$F = \frac{4}{3} \times \sigma_{max} \times \frac{h}{3} \times L$$

$$R = \frac{X \times \sigma_{max} \times L}{2}$$

$$Q = h \times L \times W \times \rho$$

ρ = density of concrete

Note: Moment and horizontal load are multiplied by 1.5 to satisfy the safety requirement for overturning.

6. Calculation of Footings cont.

a). Hypotheses

- the ground bearing pressure is zero at surface level
- the pressure is increases to a maximum at B and becomes zero once more at C
- the distribution of pressures from A to C is parabolic
- the center of rotation of the footing, is about the point where R crosses the bottom face of the footing
- the distribution of pressures on the lower face is triangular
- the pressure is at a maximum at E
- the pressures at B and E reach their maximum values simultaneously

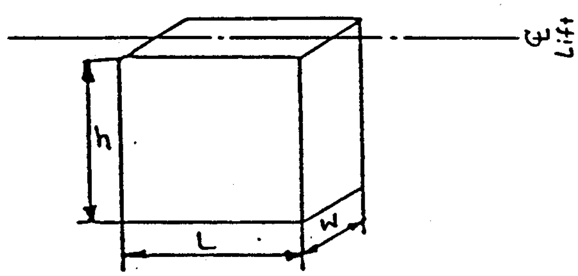
b). Conditions of equilibrium

$$R = P + Q$$

$$M + (H \times h) = F \times \frac{2h}{3} + (P + Q)\left(\frac{W}{2} - \frac{x}{3}\right)$$

c). Method of calculation

We give a range of possible values for the length and width of the footing



The programme selects the minimum value in the range and then calculates the height necessary to obtain equilibrium

if the ratio $\frac{\text{height}}{\text{length}}$ or $\frac{\text{height}}{\text{width}}$

is greater than 1.4, the programme automatically increases the width by 10cm and then recommerces the calculation.