THE PAPUA NEW GUINEA UNIVERSITY OF TECHNOLOGY

DEPARTMENT OF CIVIL ENGINEERING – 4TH YEAR DEGREE

SECOND SEMESTER EXAMINATIONS - 2021

CE 412 – STRUCTURAL ANALYSIS AND DESIGN (ELECTIVE)

DATE: MONDAY, 1ST NOVEMBER 2021 – 12:50 P.M.

VENUE: C004/5

TIME ALLOWED: 3 HOURS

INFORMATION FOR CANDIDATES

1. You have 10 minutes to read the paper before the examination starts. You must **not** begin writing during this time.
2. **There are FOUR (4) Questions in this paper. Attempt all FOUR (4) Questions.**
3. Use only ink. Do not use pencils for writing except for drawings and sketches.
4. Start each question on a new page and show all your calculations in the answer book provided. No other material will be accepted.
5. Write on **one side of the page only** and keep the margins clear.
6. Calculators and drawing equipment are permitted in the examination room. Information sheet on cable profiles, photocopies of AS 3600-2001 and ONESTEEL Reinforcing Data are allowed in the examination room. Note and textbooks are not allowed.
7. **Write your NAME and Student NUMBER clearly on the front page. Do it now.**
8. Marks for each of the question are given within parenthesis at the end of each question.
9. **Switch your mobile phone OFF.**

QUESTION ONE

A typical frame in a 2 storey shear building is shown in Figure 1. Determine the natural frequencies of vibration and the associated mode shapes. The column masses have been lumped (included) in the masses given at each floor level. The mode shapes must be plotted with respect to a vertical axis. (Note assume $EI/mL^3 = 10$).

(20 Marks)

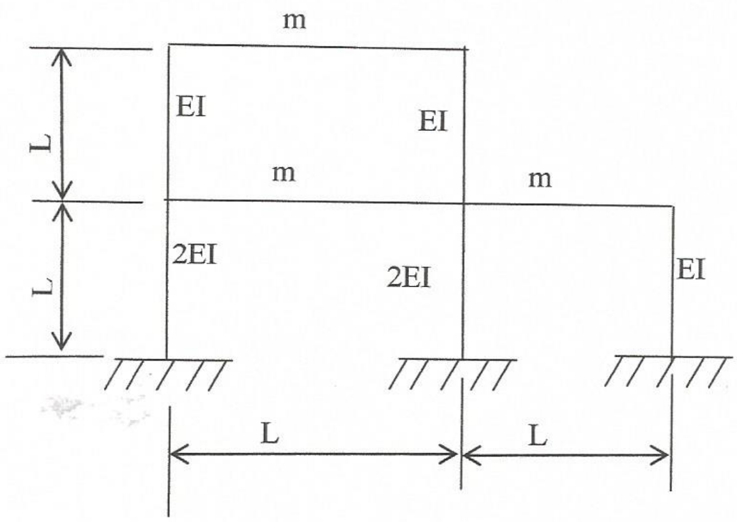


Figure 1

QUESTION TWO

Using the post tensioned concrete, determine the number of strands and the profile of the tendons required to support the beam shown in Figure 2. Note that the point load at the mid-span of the simply supported beam and the uniformly distributed loads are directed downwards. (Note also that P_G and W_G denote the dead load while P_Q and W_Q denote live load). The size of the beam is as shown in Figure 2. The design is to comply with the following criteria:

(i) Determine number of strands, cable profile and jacking force assuming 25 %losses and balance 100% of the dead load.

(ii) Determine the ultimate flexural moment at mid-span and any additional flexural reinforcement required to resist the given loadings given the following material properties:

(30 Marks)

f'c = 40 MPa

Cover = 30 mm to reinforcement
= 125 mm to centre of tendon

7 wire super strand to AS 1311 – 12.7 mm diameter
f_p = 1840 MPa
A_p = 100 mm^2 per strand
Tendons jacked to 80% of f_p

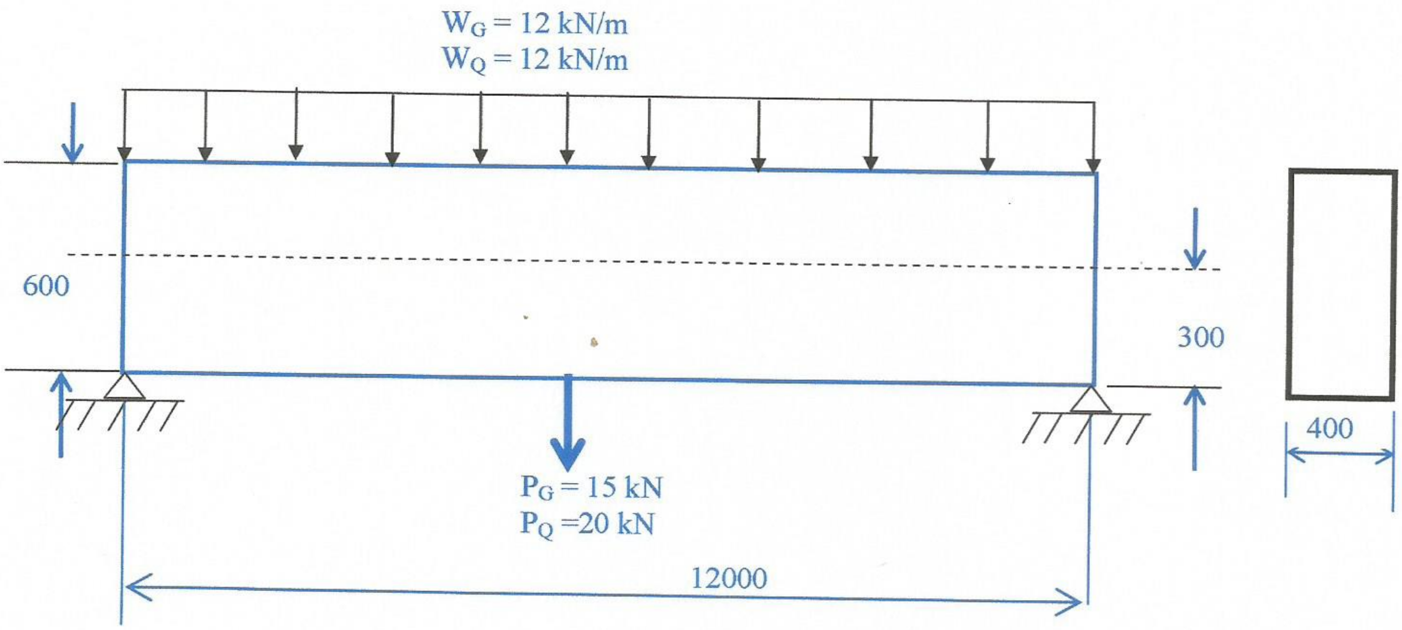


Figure 2

QUESTION THREE

Design the perpendicular shear reinforcement (at distance d from the support) using R10 stirrups for a simply supported beam spanning 20 metres and supporting a live load (unfactored) of 12.5 kN/m and it's own self weight (assume density of concrete is 25 kN/m^3). The cross-section of the beam is shown in Figure 3 and assume the centroid is the critical section for V_t and 20% losses which is uniform along the length of the beam.

(25 Marks)

$f'c = 40$ MPa

$f_{sy} = 400$ MPa

$A_{st} = 3075\ mm^2$
$A_{sc} = 226\ mm^2$

$A = 365,000\ mm^2$

$I_{xx} = 54.4 \times 10^9\ mm^4$

7 wire super strand to AS 1311 – 12.7 mm diameter

$f_p = 1840$ MPa
Tendons jacked to 80% of f_p

$E_c = 32,000$ MPa
$e = 445$ mm (Mid-span)
$y_{bottom} = 575$ mm
$A_p = 1433\ mm^2$

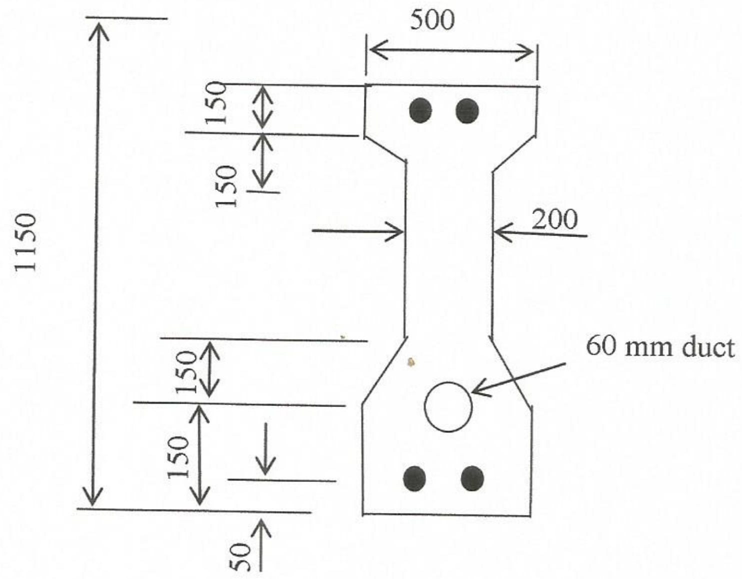


Figure 3

QUESTION FOUR

Determine the equivalent loads due to prestress for the beam shown in Figure 4. The prestress force may be assumed to be constant along the length of the beam and may be taken as 1500 kN. Summarize the equivalent loads on a line diagram of the structure. (note: all dimensions are in mm).

(25 Marks)

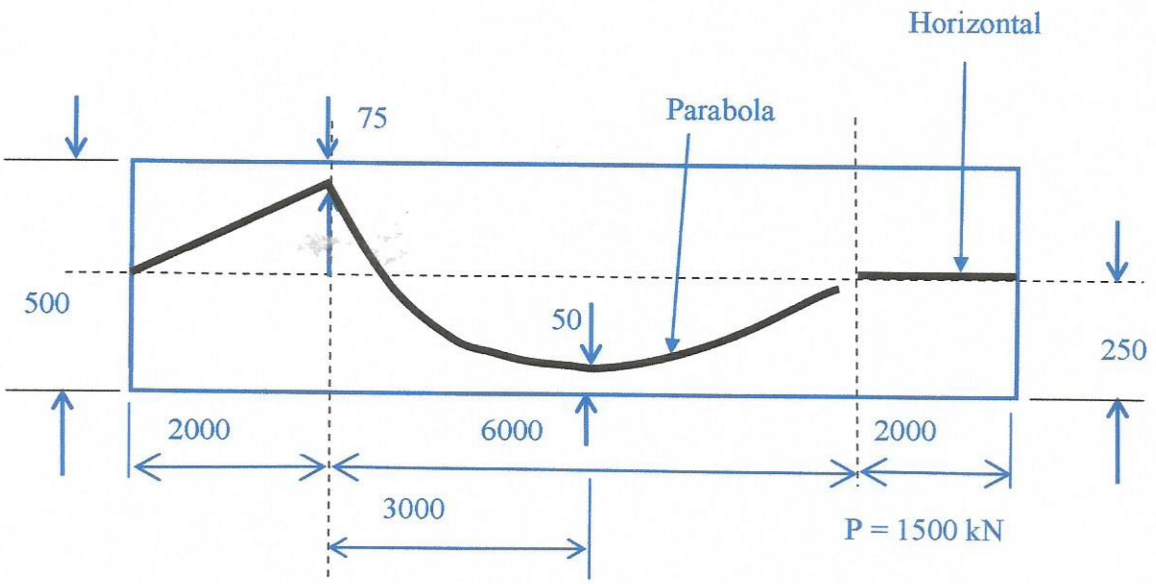


Figure 4

END OF PAPER

TABLE 6.3.1

TENSILE STRENGTH OF COMMONLY USED WIRE STRAND AND BAR

Material type and Standard	Nominal diameter mm	Area mm^2	Minimum breaking load kN	Minimum tensile strength (f_p) MPa
Wire, AS 1310	5 5 7	19.6 19.6 38.5	30.4 33.3 65.5	1 550 1 700 1 700
7-wire super strand, AS 1311	9.3 12.7 15.2	54.7 100 143	102 184 250	1 860 1 840 1 750
7-wire regular strand, AS 1311	12.7	94.3	165	1 750
Bars, AS 1313 (Super grade only)	23 29 32 38	415 660 804 1 140	450 710 870 1 230	1 080 1 080 1 080 1 080

6.3.2 Modulus of elasticity

The modulus of elasticity of tendons (E_p) may be either—

(a) taken as equal to—

(i) for stress-relieved wire to AS 1310 .... 200×10^3 MPa;

(ii) for stress-relieved steel strand to AS 1311 .... 195×10^3 MPa;

(iii) for cold worked high tensile alloy steel bars to AS 1313 .... 170×10^3 MPa; or

(b) determined by test.

Consideration should be given to the fact that the modulus of elasticity of tendons may vary by ±5% and will vary more when a number of tendons are combined into a single cable.

6.3.3 Stress-strain curves

A stress-strain curve for tendons may be determined from appropriate test data.

6.3.4 Relaxation of tendons

6.3.4.1 *General*

This Clause applies to the relaxation, at any age and stress level, of low-relaxation wire, low-relaxation strand, and alloy-steel bars.

6.3.4.2 *Basic relaxation*

The basic relaxation (R_b) of a tendon after one thousand hours at 20°C and $0.7f_p$ may be either—

(a) taken as equal to, for Australian manufactured materials—

(i) low-relaxation wire..

(ii) low-relaxation strand 1%;

(iii) alloy-steel bars 2%;

(b) determined in accordance with AS 1310, AS 1311, or AS 1313 as appropriate. .... 3%; or

SUMMARY OF EQUIVALENT LOADS DUE TO PRESTRESS

CABLE SHAPE	EQUIVALENT LOAD	COMMENTS

Kinked

Θ in radians

Curved

$$w = P\frac{d^2y}{dx^2}$$

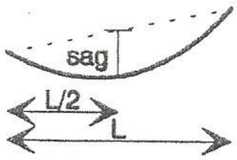
small angles only

Straight cable

0.0

no transverse load induced by a straight cable

Parabolic cable



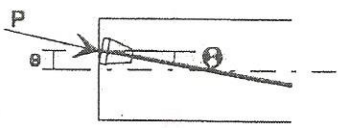
$$w = \frac{8Psag}{L^2}$$

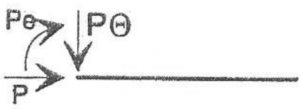
uniformly distributed load

Cubic cable

linear variation in load

Anchorages





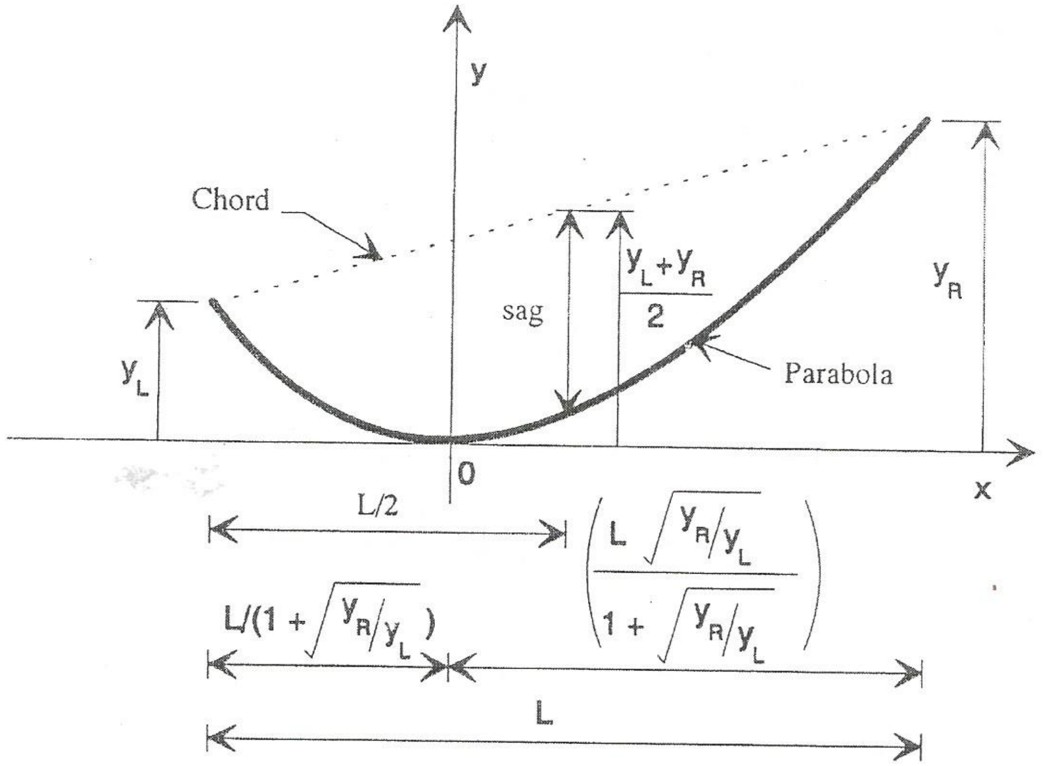
vertical:

$$PSin\Theta \approx P\Theta$$

horizontal:

$$PCos\Theta \approx P$$

EQUATIONS OF A PARABOLA

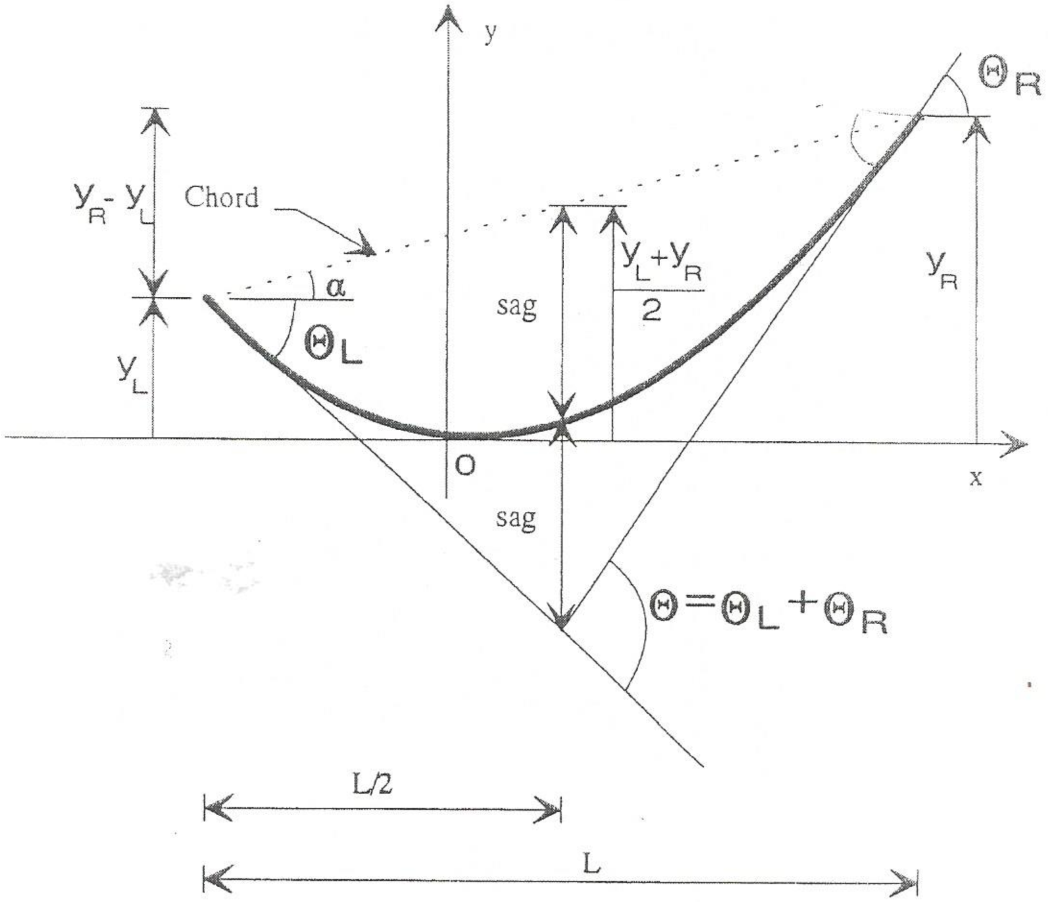


The skewed parabola as illustrated above has its origin located at the minimum point of the parabola. The equation of this parabola is:

$$y = y_L\left(1+\sqrt{\frac{y_R}{y_L}}\right)^2\left(\frac{x}{L}\right)^2$$

$$sag = y_L\left(1+\sqrt{\frac{y_R}{y_L}}\right)^2 / 4$$

Often the sag is approximated as $(y_L+y_R)/2$. For the case of a skewed parabola as shown above and typical tendon profiles this is a reasonable approximation. For example the most skewed parabola occurs in the end span. For a rectangular beam $y_L/y_R = 0.5$ and the corresponding sag is 97% of $(y_L+y_R)/2$. Hence by ignoring the skew effect gives an underestimate of the prestress required to balance a load by up to 3%. In the case of T beams the centroid moves up, thus reducing the error.



$$\alpha = \frac{y_R - y_L}{L}$$

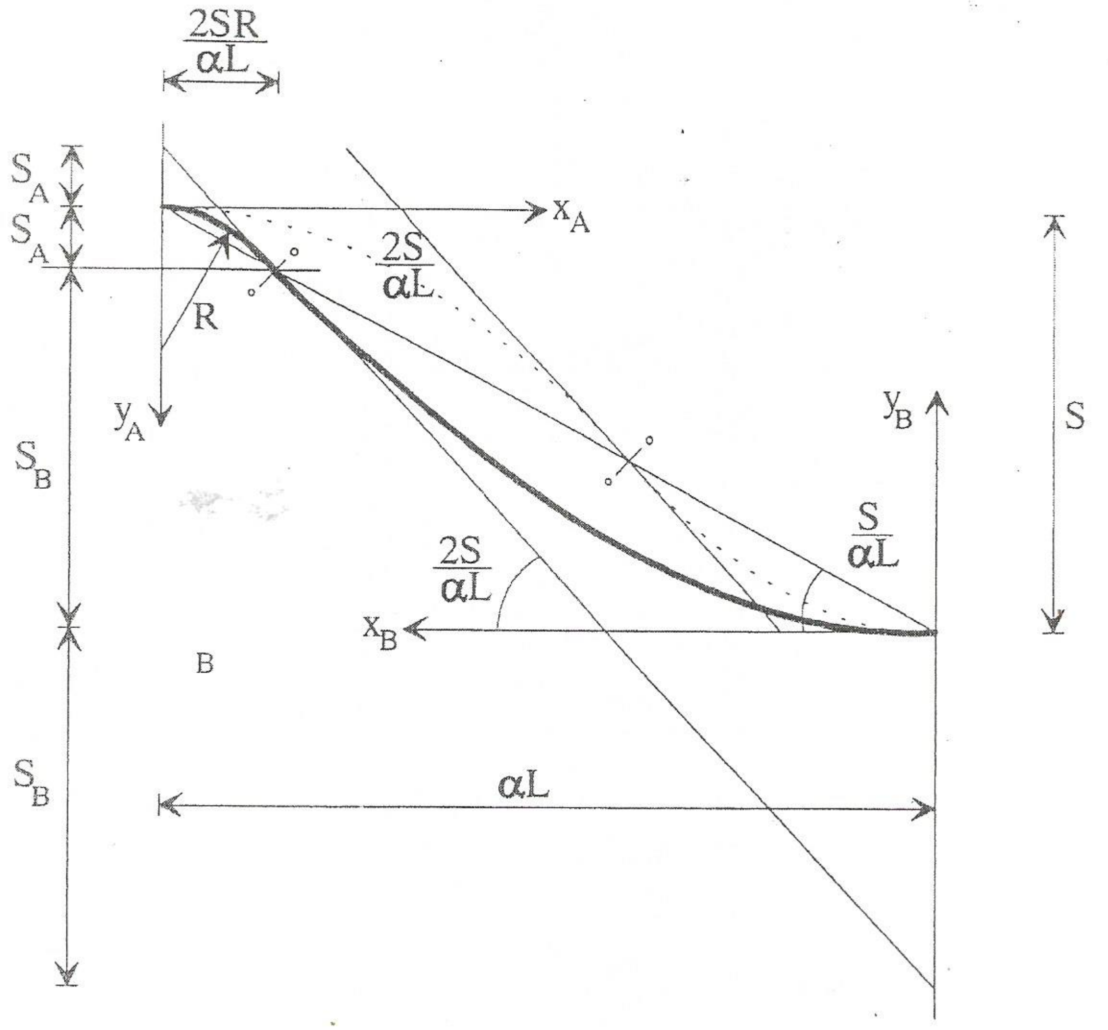
$$\alpha + \Theta_L = \frac{4sag}{L}$$

$$\Theta_L = \frac{4sag}{L} - \frac{y_R - y_L}{L}$$

$$\Theta_R = \frac{4sag}{L} + \frac{y_R - y_L}{L}$$

$$\Theta = \frac{8sag}{L}$$

Properties of two tangential parabolas



- Tangent points always on a striaght line between the horizontal tangent points
- Slope at tangent point is always = $2S/\alpha L$
- Total absolute angle change in angle between horizontal tangents always = $4S/\alpha L$
- All of the above are independent of the radius R.
- Equation to parabola A is $y_A = \dfrac{x_A^2}{2R}$
- Equation to parabola B is $y_B = \dfrac{Sx_B^2}{(\alpha L)^2 - 2RS}$