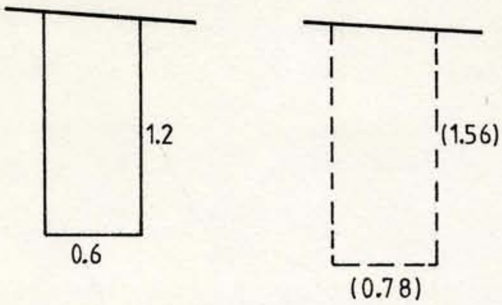
APPENDIX 5

INFLUENCE OF LIFT / DRAG RATIO :-

To illustrate possible beneficial effects of increase in rudder area for a sail craft rudder; consider the rudder design for a One-Tonner :-



Assume existing design with $AR_G = 2$ (Assumed $AR_E = 4$) with chord 0.6 m span 1.2 m (hence area $0.72\ m^2$) is required to operate at 10^o attack in order to produce the desired sideforce at say 6 knots (3.09 m/s)

From Figure 6a, at $\alpha = 10^o$ for $AR_E = 4$, $C_L = 0.638$ and $\frac{L}{D} = 13.6$
Assuming AR remains unchanged, angle of attack for max. L/D is 6^o, when L/D = 17; at $\alpha = 6^o$, $C_L = 0.38$.

$$C_L = \frac{L}{\frac{1}{2}\rho A V_R^2}$$

Hence for same lift, $A \propto \frac{1}{C_L}$

and new Area $= 0.72 \times 0.638/0.38 = 0.72 \times 1.679 = 1.21\ m^2$

(hence new $\bar{c} = \sqrt{\frac{Area}{AR_G}} = \sqrt{\frac{1.21}{2}} = 0.777$ m

and new S = 1.21/0.777 = 1.56 m

For original area, At 10^o, $C_D = 0.045$, and $D = C_D \times \frac{1}{2}\rho A V_R^2$

$$= 0.045 \times \frac{1025}{2} \times 0.72 \times 3.09^2$$

$$= 158.6\ N$$

For new area, At 6^o, $C_D = 0.022$ and D $= 0.022 \times \frac{1025}{2} \times 1.21 \times 3.09^2$

$$= 130.3\ N$$

i.e. a saving in drag of 28.3 N i.e. approx. 18%

The minimum drag coefficient (as $\alpha \to 0$) for both rudders is approximately the same at 0.01 and increase in drag for the new design will be proportional to the increase in area.

i.e. for original design, drag $D = 0.01 \times \frac{1025}{2} \times 0.72 \times 3.09^2$

$$= 35.2\ N$$

for new design $$D = 0.01 \times \frac{1025}{2} \times 1.21 \times 3.09^2$$
$$= 59.2 \text{ N}$$

i.e. an increase of 24 N i.e. approx. 68%

These simple calculations for a particular case indicate that an increase in rudder area of about 68% with subsequent decrease in angle of attack has led to a decrease in drag of 28.3 N (about 18%) whilst producing the same sideforce. This saving in drag of 28.3 N for the production of a chosen sideforce is made at the cost of an increase in drag of 24 N at zero angle of attack. It can be deduced from the data that upward of about $4\frac{1}{2}^{o}$ the larger rudder incurs less drag than the smaller rudder for the production of equal sideforce.

Such an increase in rudder area is of course only of benefit when, in order to generate a particular sideforce, the original design has to work at an angle of attack somewhat larger than that for L/D max.