3.4 Class 4 Calculations

The failure mode assumed for these calculations is shearing along the α-joints, shearing along the extension of the α-joints (through intact material) and, if necessary, tensile fracture through the intact material (across an area of t x T) with separation taking place along the ψ-joint. The ψ-joint has again been assumed to contribute nothing to the sample strength. The strength components that have been taken into account are the shearing strength of the joints and the shearing and tensile strengths of the intact material.

At failure: $DF = RF$

$$\text{or } W \sin\alpha = A_j.(C_j + \sigma_n \tan\phi_j) + T.S\,(C_m + \sigma_n \tan\phi_m) + T.t.t_m$$

$$\text{or } W = \frac{T\,(L_{j\alpha}.C_j + S.C_m + t.t_m)}{\sin\alpha - T.\dfrac{\cos^2\alpha}{A}\,(L_{j\alpha}.\tan\phi_j + S.\tan\phi_m)}$$

For plaster of paris and 2" x 9" x 12" blocks, we get:

$$W = \frac{51\,(0{,}0088\,L_{j\alpha} + 1{,}4S + 1{,}49t)}{\sin\alpha - 0{,}0035\cos^2\alpha\,(0{,}487\,L_{j\alpha} + 0{,}869S)}\ N$$

TABLE 3.3

FAILURE LOADS OF CLASS 4 SAMPLES

SAMPLE NOS.	CALCULATED (kN)	AV. EXPTL. (kN)
3	544	64,5
5	106	64,0
7	21,3	9,5
50, 53, 54, 55, 56	8,5	14,8
58, 60, 61	23,1	17,8

From this formula, the strengths tabulated in Table 3.3 were calculated. It should be noted that the minimum value of t used was zero. If the dimension was, in actual fact, negative, the value zero was used.

In this case there is very little correlation between the calculated and average experimental strengths. About all that can be said is that, generally, as the calculated values increase, so also do the experimental ones. Again the samples failed to reach the high strengths predicted when the weakening effect of the joints was small.

As stated in 3.3, these calculations could have been done using the assumption that peak strength is reached after separation has occurred along the ψ-joints. In this case σ_{n1} would have been used instead of σ_n and larger values of W would have been obtained.

3.5 Conclusions

The calculations performed in this chapter apply, in each case, to one particular mode of failure. If another mode occurs, the calculations become inapplicable and comparisons should not be made with experimental values.

The modes postulated are dependent on the joint configurations concerned, and, as such, apply more readily when the weakening effect of the configuration is large. When the weakening effect is not large enough, other modes become critical and occur.

As pointed out before the experimental results do show definite trends. For a better understanding of the failures, specially at higher loads, a more sophisticated analysis will be necessary. The author is of the opinion that especially for the stronger samples, the best understanding will be obtained from a theory for material behaviour. Seeing that the failure mechanisms of the plaster of paris seem to be typical of those involved in brittle fracture, Griffith's theory (probably modified for closed cracks) may be a worthwhile starting point for such a more sophisticated analysis. Using a finite element analysis it would also be possible to obtain a good idea of the stresses and also of the failure mechanisms. At present, work is being conducted along these lines at the University of the Witwatersrand, Johannesburg.

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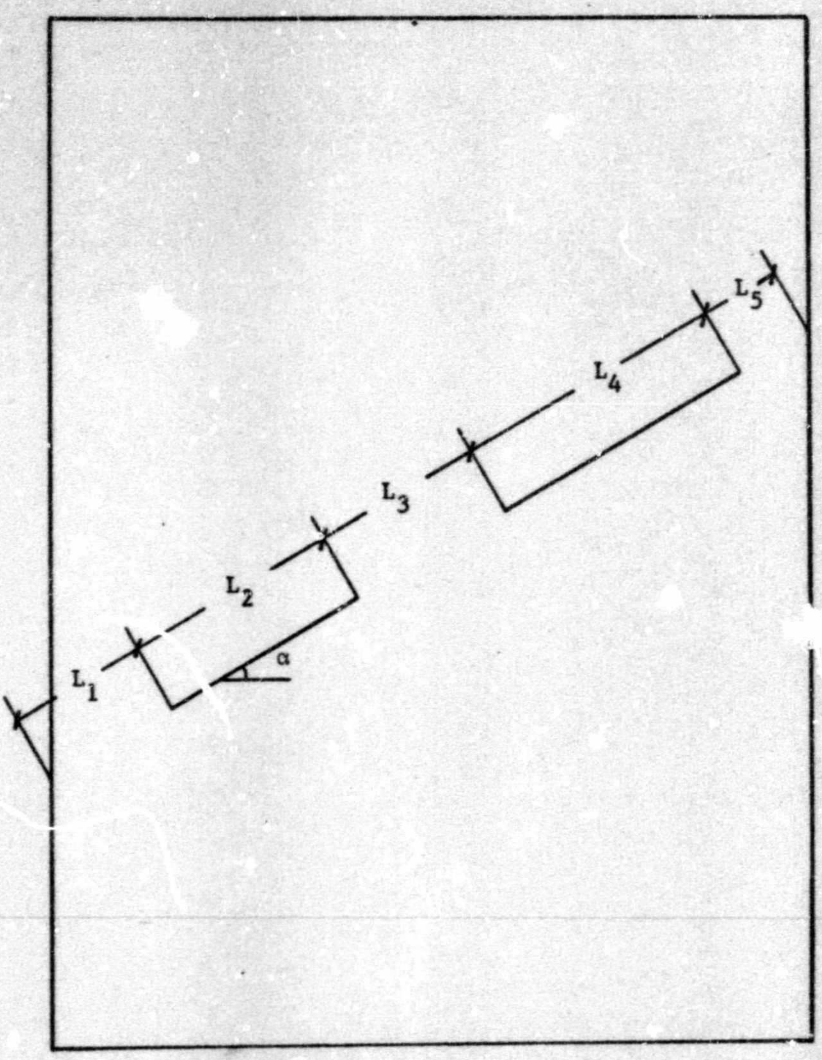
APPENDIX

A photographic record and short description of the tests carried out for this thesis.

CLASS 1

A Class 1 configuration has parallel joints in one plane.



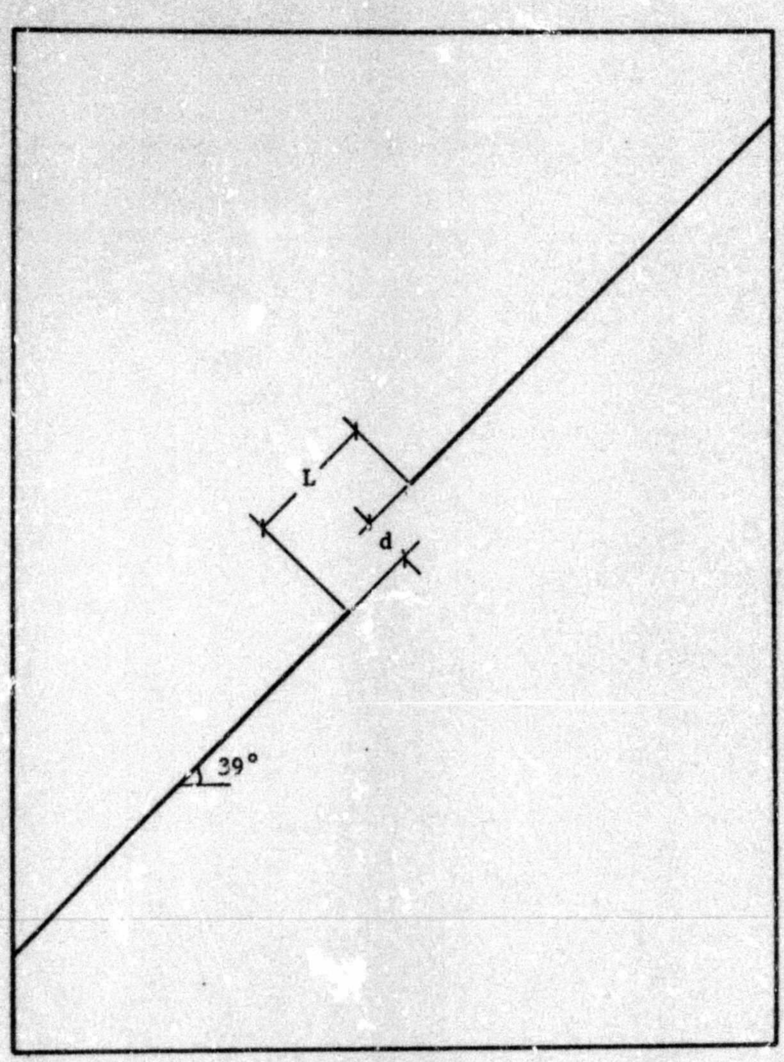
CLASS 1 MASTER DRAWING SHOWING PARAMETERS TO BE VARIED

$$\text{Continuity} = k = \frac{L_2 + L_4}{L_1 + L_2 + L_3 + L_4 + L_5}$$

Failure load = W

CLASS 2

A Class 2 configuration has parallel joints in more than one plane.

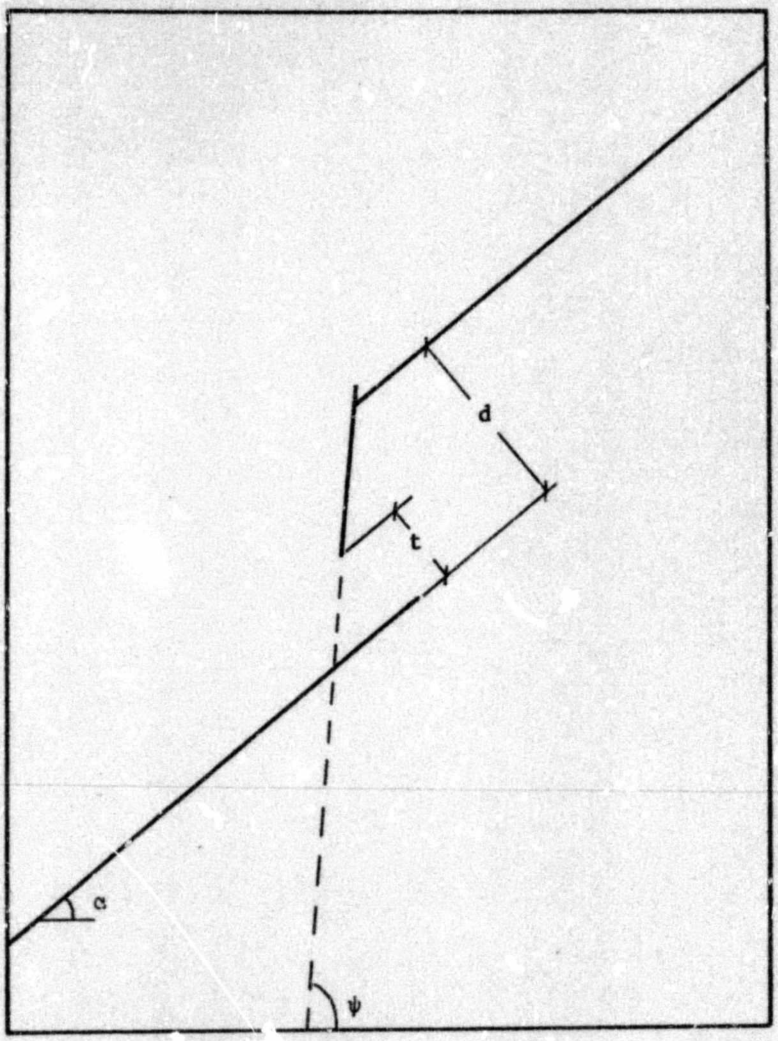


CLASS 2 MASTER DRAWING SHOWING SOME PARAMETERS

W = failure load

CLASS 3

A Class 3 configuration has joints in two directions (given by the angles α and ψ, measured from the horizontal) and a tension fracture only is required through the intact material for stepping down from one α-joint to the next.

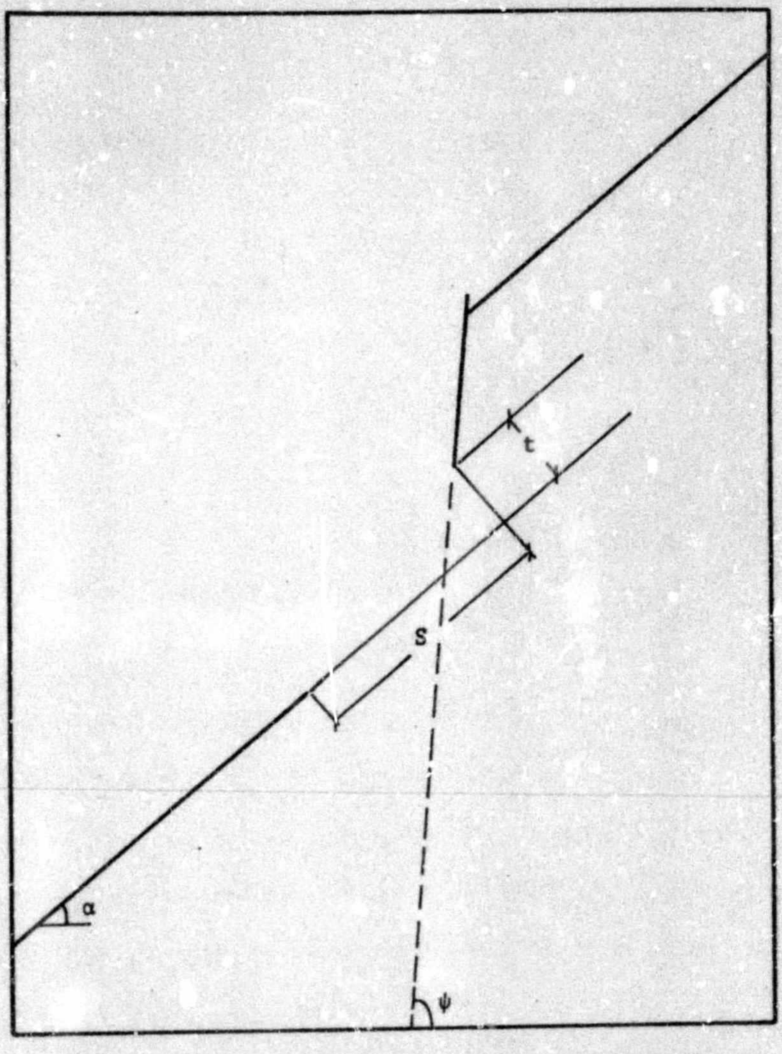


CLASS 3 MASTER DRAWING SHOWING SALIENT PARAMETERS

W = failure load

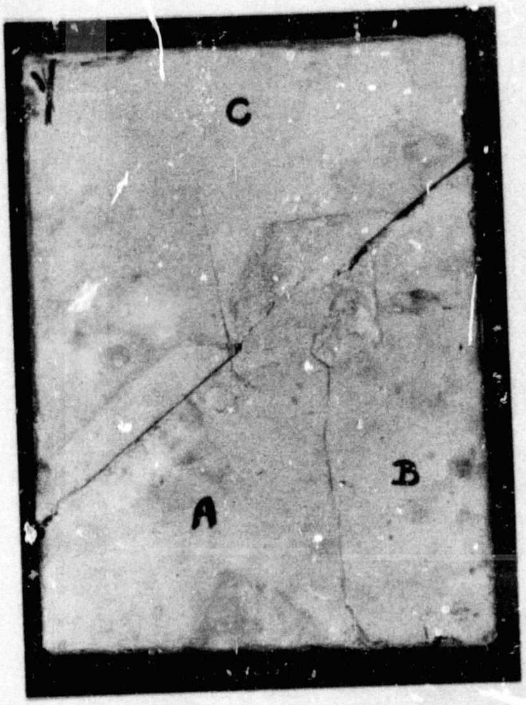
CLASS 4

A Class 4 configuration has joints in two directions (given by the angles α and ψ, measured from the horizontal) and a shearing action is required in the intact material for stepping down from one α-joint to the next.



CLASS 4 MASTER DRAWING SHOWING SALIENT PARAMETERS

W = failure load



SAMPLE NO. 1

α = 38°

k = 0,71

W = 40,9 kN

L_1 = 0 mm

L_2 = 72 mm

L_3 = 83 mm

L_4 = 131 mm

L_5 = 0 mm

MODE OF FAILURE

Two branch cracks grew from the ends of joints. One of these branch cracks led to the axial cleavage or tension fracture between pieces A and B. Shear occurred along both joints. Shear also occurred through the intact material between the joints. The shearing motion was not 2-dimensional and had a component of movement out of the plane of the model as well as in the joint direction.

SAMPLE NO. 2

d = 51 mm

L = - 20 mm

MODE OF FAILURE

Shear occurred along both joints. The intact material between the joints fractured in tension in a direction not quite perpendicular to the joints.

FAILURE LOAD

The arm was accidentally dropped onto the sample which fractured. It had already been subjected to 2,7 kN (i.e. failure load greater than 2,7 kN).

MODE OF FAILURE

Shear movement took place along both α-joints. Separation took place along the ψ-joint and a combined shear and tension fracture occurred through the intact material.

SAMPLE NO. 3

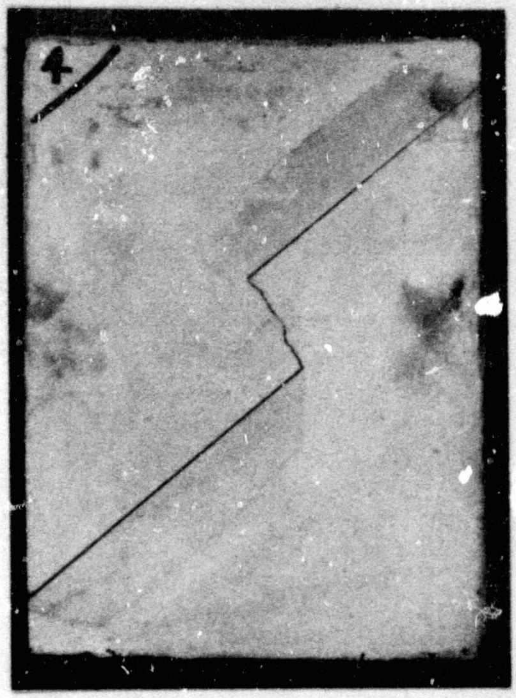
α = 30°

ψ = 80°

S = 115 mm

t = 63 mm

W = 64,5 kN



SAMPLE NO. 4

d = 51 mm

L = - 11 mm

W = 13,0 kN

MODE OF FAILURE

Shear occurred along both joints and tension fracture occurred in the intact material between the joints. The direction of this tension failure surface is not quite perpendicular to the joints.

- MODE OF FAILURE

At a load of 63,3 kN a crack appeared in the sample, from the ψ-joint downwards, past the lower α-joint. When the load was increased to 64 kN the sample failed suddenly. The mode of failure was unexptected in that separation did not take place along the ψ-joint and hence shearing could not fully occur on the upper α-joint. The striations on the failure surface through the intact material seem to be nearly parallel to the α-joints near the lower joint but much steeper higher up. These striations suggest a rotational shearing failure.

SAMPLE NO. 5

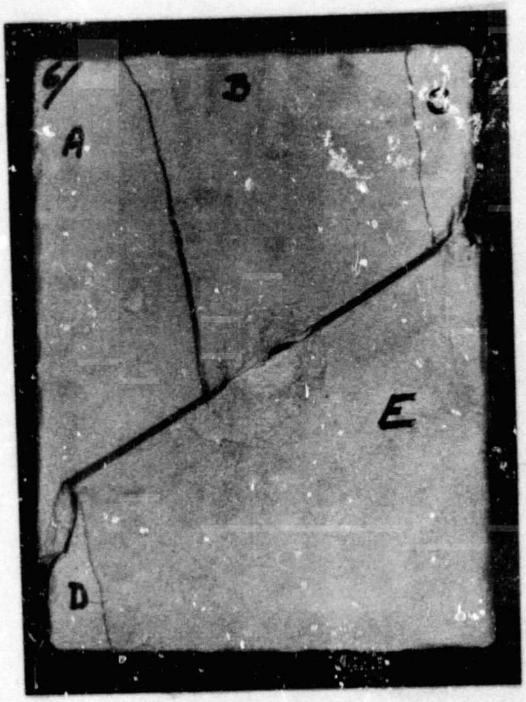
α = 30°

ψ = 83°

S = 116 mm

t = 65 mm

W = 64,0 kN



SAMPLE NO. 6

α = 30°

k = 0,64

W = 50,0 kN

L_1 = 17 mm

L_2 = 91 mm

L_3 = 56 mm

L_4 = 78 mm

L_5 = 22 mm

MODE OF FAILURE

Branch cracks grew from 3 of the 4 joint ends. These cracks lead to the almost vertical tension fractures between pieces A and B, B and C and pieces D and E. Shear occurred along both joints and through the intact material between the joints (where it was roughly in the plane of the joints).

SAMPLE NO. 7

α = 40°

ψ = 86°

S = 60 mm

t = 21 mm

W = 9,5 kN

MODE OF FAILURE

Shearing took place cleanly along both α-joints. Separation took place over most of the ψ-joint. The failure through the intact material showed striations parallel to the α-joints which suggests that a series of small shear and tension failures may have occurred to give the failure surface its actual shape.

MODE OF FAILURE

Shear movement took place along both α-joints. Separation took place along the ψ-joint. A tension fracture occurred through the intact material from the bottom of the ψ-joint, approximately perpendicular to the α-joint.

? has

SAMPLE

Random Class 3 configuration

W - not recorded

MODE OF FAILURE

Shear movement took place along both α-joints. Separation took place along the ψ-joint. A tension fracture occurred through the intact material from the bottom of the ψ-joint, approximately perpendicular to the α-joint.

FAILURE LOAD

Failure occurred as the 2,7 kN reaction was being lowered onto the sample.

SAMPLE NO. 8

α = $39\frac{1}{2}^\circ$

ψ = $93\frac{1}{2}^\circ$

d = 50 mm

t = 13 mm

MODE OF FAILURE

Shear occurred along both joints and tension fracture occurred in the intact material. The tension fracture surface did not start at the joint ends and was thus not perpendicular to the joint direction.

SAMPLE NO. 9

d = 51 mm

L = 0 mm

W = 20,6 kN

MODE OF FAILURE

Shear took place along both joint surfaces. The failure surface through the intact material showed signs of both shear and tension failures. This failure surface oscillates about the plane joining the two joint ends.

SAMPLE NO. 10

d = 51 mm

L = 81 mm

W = 15,6 kN

SAMPLE NO. 11

d = 51 mm

L = 158 mm

W = 30,9 kN

MODE OF FAILURE

A vertical tension fracture occurred upwards from the top of the bottom joint. Shear occurred along both joint surfaces and a composite tension and shear failure occurred through the intact material leaving striations on the failure surface.