TABLE II.—STRENGTH OF ANTHRACITE.

(From "Mines and Minerals," March, 1903.)

FROM	SIZE.	NO. OF TESTS.	FIRST CRACK	MAX. LOAD.
Northern Field ...	2 x 2 x 1 in. high.	122	3,022 lbs.	6,241 lbs.
do. do. ...	2 x 2 x 2 in. high.	116	2,025 ,,	4,087 ,,
do. do. ...	2 x 2 x 4 in. high.	113	1,878 ,,	2,854 ,,
Eastern Mid. Field	2 x 2 x 1 in. high.	7	4,996 ,,	7,417 ,,
do. do.	2 x 2 x 2 in. high.	6	3,343 ,,	3,857 ,,
do. do.	2 x 2 x 4 in. high.	7	3,413 ,,	3,821 ,,
West'n Mid. Field	2 x 2 x 1 in. high.	3	3,001 ,,	8,631 ,,
do. do.	2 x 2 x 2 in. high.	3	788 ,,	3,499 ,,
do. do.	2 x 2 x 4 in. high.	3	1,440 ,,	2,447 ,,
Southern Field ...	2 x 2 x 1 in. high.	12	1,124 ,,	3,814 ,,
do. do.	2 x 2 x 2 in. high.	12	1,099 ,,	2,377 ,,
do. do.	2 x 2 x 4 in. high.	12	988 ,,	1,809 ,,

These tests show in a very decided manner the effect of the increase in height of the specimen. The committee in charge of the investigation stated the following conclusions, which I have paraphrased: —

The squeezing strength of a mine pillar (of anthracite), whose width is twice its height, is about 3,000lbs. per square inch, and the crushing strength about 6,000lbs. per square inch.

That, other things being equal, the crushing strength of mine pillars would vary *inversely* as the square root of the thickness of the seam.

This apparently holds true where the height is less than the width.

In tall pillars, the crushing strength appears to diminish with height in accordance with this rule.

But the squeezing strength (or load to produce initial failure or fretting) remains nearly constant.

The obvious corollary from these is that the thicker the seam the wider should be the pillar, so as to preserve a proper proportion between the two. I have already pointed out that Government regulations, as a rule, take no account of the thickness, all seams being treated alike.

Messrs. Daniels and Moore, "Eng. and Mining Journal," August 10th, 1907, p. 263, give an account of some 45 tests of anthracite, 30 specimens being from the Philadelphia and Reading Coal and Iron Company's collieries, and 15 from the Lehigh Valley Coal Company's collieries.

Forty-two of the tests were performed on a Riehle 100,000lb. standard automatic machine, and the other three upon a Riehle 150,000lb. hydraulic machine. Omitting two specimens of odd sizes and two cracked specimens, which gave abnormally low figures, the averages of the results are as follows, the load being given in lbs. per square inch of base area:—

TABLE III.—STRENGTH OF ANTHRACITE.

(DANIELS & MOORE.)

SIZE.	No. of Tests.	Max. Load (average).	Direction of Pressure with reference to bedding plane.
2 ft. x 2 ft. x 2 ft. high	4	2,369	Pressure perpendicular to bedding plane.
2 ft. x 2 ft. x 4 ft. high	7	2,321	Pressure at 10 to 25 deg.
3 ft. x 3 ft. x 3 ft. high	2	3,390	Pressure perpendicular.
4 ft. x 4 ft. x 4 ft. high	9	1,999	Pressure perpendicular in 8 tests.
4 ft. x 4 ft. x 8 ft. high	8	1,950	2 perpendicular, 2 parallel, 4 inclined.
4 ft. x 4 ft. x 12 ft. high	4	1,405	2 perpendicular, 2 parallel.
6 ft. x 6 ft. x 6 ft. high	7	1,549	6 perpendicular.

In most of these tests the pressure was applied perpendicularly to the plane of bedding.

The chief feature of the individual results is their great variability for test pieces of the same size.

With regard to the averages given above, the effect of increase in height is so great that the small cubes are stronger than the larger ones; but so many of the prisms were tested with pressure applied at an inclination to the plane of bedding that it would be unsafe to generalise as to the effect of increase in height. Few of the test pieces had flat, parallel bearing surfaces, so that the loading was generally somewhat eccentric and not uniform. The first crack would, therefore, bear no definite relation to the load at the time, or to the ultimate crushing load, and for this reason was not given in the article mentioned.

STRENGTH OF BITUMINOUS COAL.

In addition to tests upon anthracite, Messrs. Daniels and Moore (loc. cit.) performed 14 tests upon bituminous coal from the Pittsburg Colliery. The specimens were from 3½in. x 4in. x 5in. to 7in. x 7in. x 8½in., and no two were alike. It is, therefore, impossible to say more than that the crushing strength of this particular coal varied from 584lbs. to 1,538lbs. per square inch of base area, and the average was 1,106lbs.

The 6in. x. 6in x 6in. anthracite tests gave an average of 1,627lbs. for the six specimens tested with pressure perpendicular to the plane of bedding, so that the bituminous coal appears to be about two-thirds the strength of anthracite. If tested in blocks about 3in. x 3in. x 1in. or 2in. x 2in. x 1in., there is little doubt that it would give a much better figure, just as anthracite did in the tests quoted on p. . These are the only details I have been able to find of the strength of bituminous coal, and I shall be obliged if members who know of other published figures will give particulars or the references.

Comparison Between Lignite, Bituminous Coal and Anthracite.

The dissimilarity in size of the specimens prevents a proper comparison between the three classes of material, but those which are nearest are:—

Lignite: 1¾in. x 1¾in. x 1in., giving 5,560lbs.

Lignite: 2¾in. x 2¾in. x 1in., giving 6,365lbs.

Anthracite: 2in. x 2in. x 1in., giving 3,814 to 8,631 lbs. (Table II. See p. 31).

Anthracite: 6in. x 6in. x 6in., giving 1,627lbs.

Bituminous, various: Giving 1,106lbs.

Conduct of the Tests.

Messrs. Daniels and Moore mention that they experienced considerable difficulty in sawing test pieces of coal from the blocks provided, and the surfaces were uneven when cutting had been completed. This difficulty seems to have been greatest with the larger specimens, and may to some extent account for the lower crushing strengths obtained with them. When the bearing surfaces are uneven, the ragged edges crumble and crack off when pressure is applied. In order to obtain even bearing surfaces, Messrs. Daniels and Moore used a layer of sand, and in other cases coated the bearing surfaces with a thin layer of plaster of Paris.

For Taupiri Lignite.

When the test pieces have been well cut, a piece of soft wood (Kauri) answers well in assisting to apply the pressure evenly. A pressure of 1½ ton per square inch will force the specimen into the wood to a depth of about ⅛in., and slight irregularities are accommodated; whereas application of pressure direct from a plane cast-iron surface would be almost certain to cause early crumbling.

The lignite specimens begin to "talk" or crackle gently long before any cracks are visible. This crackling seems to have a definite pitch or note, and must be due to the internal structure of the material being fairly uniform.

Modes of Failure.

Mr. Gibson states that the lignite specimens held up remarkably well when quite near to their ultimate crushing load. The pyramids of failure have already been discussed (p. 29). Messrs. Daniels and Moore state that with bituminous coal vertical cracks first appeared, and failure occurred by the specimen bulging out and crushing fine, but not by splitting or flying apart, as was the case with anthracite. The anthracite split vertically, and usually pieces flew off without warning.

Conclusions.

I consider the figures which have been quoted show that—

1. Small specimens are less liable to be defective than large ones.
2. Square blocks are stronger than rectangular ones having the same base area.
3. Increase in height greatly decreases the strength of the specimen or pillar.
4. Test pieces should be cut in square blocks, such that

$$\frac{\text{length of side}}{\text{height}} = \frac{\text{width of pillar}}{\text{height of pillar}}$$

but 3in. x 3in. x 1in. appears to be the limit of size of slab which can be cut. 2in. x 2in. x 1in. appears to be the most suitable for ordinary work.

With regard to the possible benefit which may be derived from such tests, they can only be applied strictly to cases of possible "crush," *i.e.*, when the roof is stronger than the coal, so that the latter will be first to give way. In such cases "crush" can be prevented by designing the pillars (square ones) of such a size as to give an ample factor of safety.

No. of Specimen.	Cross-section of nominal 1 in. Cubes.	Area sq. in.	Initial failure by cracks.		Mean.	Crushing Load.		Mean.	REMARKS.—Load in all cases applied perpendicularly to bedding plane, in which cross-section is also measured.
			lbs.	per sq. in.		lbs.	per sq. in.		
					RUN OF MINE LIGNITE.				
1	1·03 in. x 1·03 in.	1·06	3,400	3,200	3,410	5,000	4,720	5,405	Fretting at edges at 2,200. Cracks at 3,400. Well defined cracks at 4,000.
2	1·04 in. x 1·04 in.	1·08	3,600	3,340		6,890	6,400		Fretting at edges at 2,500. Pieces flaked off at 6,100.
3	1·08 in. x 0·96 in.	1·035	3,500	3,380		5,250	5,060		Fretting at edges at 3,000. Cracks open at 4,600, but carried load steadily for 4 mins.
4	1·05 in. x 0·97 in.	1·02	3,800	3,720		5,640	5,440		Fretting at edges at 3,100. Flaking off and splitting from 5,100 to failure at 5,640.
B′	1·07 in. x 1·02 in.	1·09	Damaged (broke up before load was applied.)						
B″	1·09 in. x 1·05 in.	1·145	2,100	1,830		2,400	2,100		Imperfect specimen. Broken at edges. Very irregular in form of failure.
C	1·00 in. x 1·13 in.	1·13	3,700	3,280		5,850	5,170		Cracked sample. Fretted at 2,800. Flaking and splitting slightly from 4000. Typical failure. Not included in taking mean of results.
					FRETTED LIGNITE.				
1	1·04 in. x 1·00 in.	1·04	2,700	2,600	2,520	5,275	5,070	4,738	Fretting at edges at 2,000. Definite pyramidal form of failure.
2	0·98 in. x 1·00 in.	0·98	2,500	2,560		3,750	3,820		Fretting at edges at 2,100.
3	1·05 in. x 1·03 in.	1·08	2,800	2,580		3,750	3,480		,, at edges at 2,100.
4	1·01 in. x 1·05 in.	1·06	2,200	2,080		5,850	5,520		Fretting and cracks at 2,200, stood up to a load of 4,200 for 5 min. without apparent change. Carried 5,500 with fretting and cracks wide open for 3 min. failure at 5,850.
5	1·00 in. x 1·05 in.	1·05	2,100	2,000		4,650	4,420		Cracks and fretting at 2,100. At 4,100 cracks right open but sustained the load.
6	1·04 in. x 1·02 in.	1·06	3,500	3,300		6,500	6,120		Fretting at 2,500. Cracks opened out at 5,500, but sustained the load.

Typical form of failure: a pyramid with angle of 20 to 30 deg. at the base. Material shattered.

(Signed) A. J. GIBSON.

APPENDIX B.—COMPRESSION TESTS OF RUN-OF-MINE LIGNITE.

FOR PROFESSOR JARMAN.

P. N. RUSSELL ENGINEERING LABORATORY, UNIVERSITY OF SYDNEY. July 3rd, 1908.

No. of Specim'n	DIMENSIONS.	Area of cross-section.	Load at cracking.	Ditto per sq. in.	Load at fretting	Ditto per sq. in.	Crushing load.	Ditto per sq. in.	REMARKS.
1	4in. x 1·2in. x 1in. high.	4·8	3,000	625	10,062	2,100	20,000	4,170	
2	do. do.	4·8	6,750	1,405	14,822	3,090	19,775	4,120	
		Mean ...	...	1,015	—	2,595	—	4,145	
3	2¾in. x 2¾in. x 1in. high.	7·55	19,100	2,530	38,250	5,075	53,800	7,130	
4	do. do.	7·55	2,000	2,650	—	—	26,000	3,450	Crushed completely at 26,000, evid. faulty specimen
5	do. do.	7·55	14,000	1,855	23,000	3,050	42,500	5,630	Corner broke off at 35,000. Crushed comp. at 42,500 after holding load for about 1 min.
	Mean (of 3 & 5)			2,192	—	4,062	—	6.380	
6	1¾in. x 1¾in. x 1in. high.	3·06	—	—	—	—	5,000	—	Specimen badly cut. Crushed without holding this load.
7	do. do.	3·06	5,700	1,862	10,000	3,270	17,000	5,560	Held a load of 15,000 for about 1 min. Crushed completely at 17,000.

The specimens were all cut with their 1 in. of height at right angles to the plane of bedding. Pressure was therefore perpendicular to the bedding.

(Sgd.) A. MORRISON, B.E.

It is remarkable that so little work has been done upon this subject, which is obviously of great importance to coal-mining engineers.

The present paper is merely of a preliminary nature, and is intended to collect and present in a convenient form the information already available upon the subject, as well as to describe a case in point. I trust that Sydney graduates will carry the subject further, with special reference to Australian coals, which present an attractive variety. The ideas in this paper cannot be said to be new, but they have not, as yet, attracted great attention in Australasia. Information upon the subject is badly needed, and would receive wide publication.

My best thanks are hereby tendered to Messrs. Gibson and Morrison for performing the tests already mentioned; to the directors of the Taupiri Coal Mines, Ltd., for permission to publish information relating to Ralph's mine; and to the mine manager, Mr. Ed. Wight, for a copy of the mine plan.