MODIFIED SOIL/BLOCK TECHNIQUE FOR ASSESSING WOOD DECAY

M. E. HEDLEY and J. B. FOSTER
Forest Research Institute, New Zealand Forest Service, Rotorua

(Received for publication 14 October 1971)

ABSTRACT

A modification of the standard soil/block technique for assessing the natural durability of timber is described. One block was buried flush with the soil surface and another was set directly on top of it. Lower blocks attained a moisture content suitable for decay more rapidly than did the upper blocks. Except for **Pinus radiata** D. Don sapwood blocks decayed by brown rot fungi, all the lower blocks lost more weight than upper blocks. This was particularly noticeable when durable or moderately durable timber was tested against white rot fungi. Results from lower blocks showed a better correlation with field results than did those from upper blocks.

INTRODUCTION

During evaluation of the natural durability of timber and of wood preservatives by the soil/block technique (ASTM, 1967a, 1967b) using white rot fungi, weight losses of the test blocks have often been lower than expected, but the feeder strip below them has suffered considerable decay. This indicates that the wood rotting potential of the white rot fungi has not been realised in the test blocks. To examine and assess this observation, a modified form of soil-block testing was devised.

Normal procedure for laboratory assessment of wood decay is to record the weight losses of test blocks exposed to wood decay fungi. In this way, either the natural durability of the timber or the efficacy of wood preservatives may be investigated. Either malt agar (BS, 1961) or soil (ASTM, 1967a, 1967b) may be used as a substrate for the test fungus.

Leutritz (1939) first proposed the use of soil as a substrate. His weighed test blocks were placed on a layer of soil in screw-top jars at a moisture content suitable for growth of the decay fungus. More soil was added until the blocks were almost covered and the jars were sterilised by autoclaving. When cooled, an exposed corner of each block was inoculated with the decay fungus. Blocks were buried in the soil to maintain a uniform moisture content within them.

Later (Leutritz, 1946), this method was replaced by one in which the blocks were sterilised before they were added to the soil jars, which contained a non-resistant sapwood strip ("feeder strip") placed on the soil surface. After autoclaving, the feeder strip was inoculated with the test fungus which was allowed to become established thereon before sterile test blocks were placed on it.

Duncan's (1958) series of investigations on this test method resulted in its adoption by the American Society for Testing and Materials and inclusion in ASTM standards D-2017 and D-1413. Main advantages of this method over the original are that the mycelium of the decay fungus grows more uniformly during the initial stages of the test, fresh inoculum is not placed directly onto the test blocks, and removal of the blocks at the termination of the test is facilitated.

This test method has been used extensively by the Wood Preservation Section of the Forest Research Institute, Rotorua. However, the feeder strips usually decayed to a greater extent than the test blocks, particularly when using white rot fungi. It was surmised that if the test blocks were placed in direct contact with the soil, as the feeder strips had been, then weight losses caused by white rot fungi should be increased.

EXPERIMENTAL

Effect of Block Position on Intensity of Decay

Materials and Methods

Screw-topped preserving jars (1.2 l capacity) were half filled with 400 g loam soil at a moisture content, recommended in ASTM standard D-2017, of 130% water holding capacity (WHC). As used here, the term "water holding capacity" is Duncan's (1958) laboratory estimate of "field capacity".

Sapwood blocks of *Pinus radiata* D. Don and *Populus* × euramericana (Dode) Guinier cv "regenerata" (henceforth referred to as *P. robusta)* 19 × 19 × 19 mm were selected from store and matched in pairs, both blocks of a pair being equal in weight and number of annual rings. All blocks were numbered, each block of a pair having the same number and either A or B as a suffix. Blocks were conditioned to an equilibrium moisture content (e.m.c.) of 12% and weighed. Four B blocks of the same species of timber were placed in each jar, pressed down into the soil in such a way that the upper transverse surface was flush with the soil surface. Matching A blocks were then placed on the exposed surface of the B blocks, maintaining the same annual ring orientation. A feeder strip of the same species as the timber under test, measuring 64 × 13 × 35 mm was placed between the blocks. This "double block" arrangement is shown in Fig. 1. The jars were then autoclaved at 120°C for 20 min and allowed to cool.

Ten species of wood decay fungi (Table 1) were used in the test. Six were named isolates originally obtained from the Division of Forest Products, CSIRO, Melbourne, and four were unidentified local isolates. Five of the fungi were brown rots and five were white rots. Inocula obtained from actively growing malt agar cultures were placed on the feeder strip so that each fungus was inoculated into two jars each of *Pinus radiata* and *Populus robusta.* The jars were then incubated at 27°C for 10 weeks. Following incubation, the blocks were removed from the jars, surface mycelium and adherent soil were brushed off and the blocks placed in the equilibrium moisture content (e.m.c.) room to equilibrate at 12% moisture content. Each block was then weighed and the mean weight losses of the A blocks and the B blocks exposed to each fungus were determined.

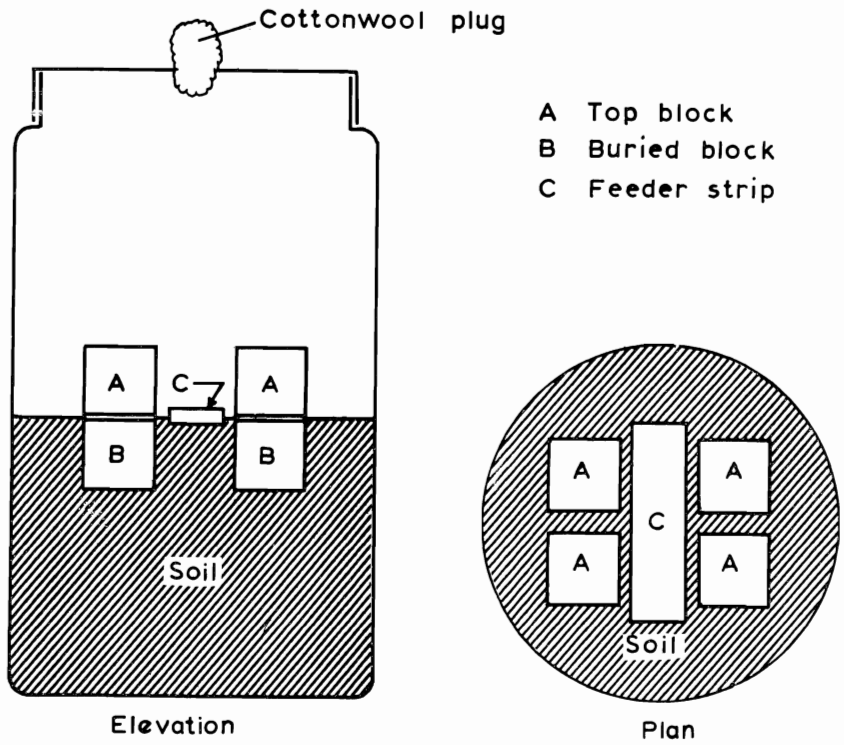

FIG. 1—Arrangement of blocks and feeder strips in soil jars.

Results

Percentage weight losses, with standard deviation, are given in Table 1.

White rots: The most noticeable feature is the differences between weight losses sustained by the A and B blocks. For each fungus and each species of timber, the blocks in soil contact were decayed to a greater extent than the corresponding upper blocks.

Brown rots: No such clearly defined disparity occurred in decay by brown rot fungi. Upper blocks of *Pinus radiata* tended to have greater weight losses than the lower blocks, but with *Lenzites trabea* (Pers.) Fr. and U28, the losses were similar. Lower blocks of *Populus robusta* had greater weight losses than upper blocks.

By arranging the blocks in close contact with the soil, the degree of attack by white rot fungi was invariably increased, whereas with brown rot fungi it was increased only in *P. robusta* in that position.

An extension of this investigation was then made to compare decay resistance ratings obtained with "double block" laboratory tests with those obtained by field tests with stakes for a number of species of different natural durabilities. Heartwood blocks of seven species were prepared as described above and inoculated with *Fomes gilvus (Schw.)* Lloyd (white rot) and *Lenzites trabea* (brown rot). Results (Table 2) provide further evidence of the disproportionate attack on upper and lower blocks.

Fomes gilvus caused no significant weight losses in the A blocks of any of the species of timber. However, all the B blocks were decayed to some extent; the weight

TABLE 1—Mean percent weight losses of A and B blocks decayed by 10 species of wood decay fungi

Fungus		Pinus radiata % weight loss	s*	Populus robusta % weight loss	s*
WHITE ROTS					
Fomes gilvus DFP2442†	A	19.8	1.1	42.2	6.4
	B	28.8	4.5	82.9	3.2
Pycnoporus coccineus DFP1096†	A	12.2	2.3	24.7	1.8
	B	20.2	3.9	38.4	3.0
Coriolus versicolor DFP7521†	A	5.3	2.2	19.5	2.9
	B	22.2	6.6	27.5	4.7
U11‡	A	21.1	3.0	24.0	4.6
	B	28.3	3.1	27.3	1.6
U14‡	A	0.5	—	6.3	1.4
	B	7.9	—	19.7	2.1
BROWN ROTS					
Lenzites trabea DFP7520†	A	60.0	3.2	33.3	5.2
	B	61.8	2.9	65.7	8.2
Coniophora olivacea DFP1779†	A	16.1	9.1	43.1	4.3
	B	6.9	6.3	47.9	3.9
Poria monticola DFP7522†	A	53.6	3.0	43.6	1.3
	B	44.6	5.6	60.0	0.9
U28‡	A	31.9	5.0	47.9	3.3
	B	29.1	3.1	61.6	1.9
U1‡	A	50.9	4.5	46.3	3.9
	B	33.3	10.5	57.4	3.6

* Standard deviation.

† Division of Forest Products, CSIRO, Melbourne accession number.

‡ Unidentified local isolate.

TABLE 2—Mean percent weight losses of seven timber species decayed by **Fomes Gilvus** and **Lenzites trabea**

Timber species		**Fomes gilvus** % weight loss	s*	**Lenzites trabea** % weight loss	s*
Podocarpus totara	A	0.1	—	2.0	1.8
	B	2.9	1.3	10.2	7.3
Eucalyptus pilularis	A	0.0	—	0.0	—
	B	5.3	5.5	0.9	—
E. botryoides	A	1.2	—	0.0	—
	B	18.7	1.6	0.2	—
E. saligna	A	1.5	0.8	0.1	—
	B	19.3	1.9	1.4	—
Cupressus macrocarpa	A	0.0	—	1.7	1.0
	B	15.4	2.2	16.2	10.7
Sequoia sempervirens	A	0.0	—	34.5	3.6
	B	17.4	1.2	44.8	4.1
Thuja plicata	A	0.0	—	22.3	5.4
	B	6.8	2.5	49.7	5.5

* Standard deviation.

Weight losses below 2.0% are not considered to be significant.

losses of *Eucalyptus saligna* J. E. Smith, *E. botryoides* Sm., *Cupressus macrocarpa* Hartw., and *Sequoia sempervirens* (Lamb. ex D. Don) Endl. were the most noteworthy. Decay by *Lenzites trabea* was also concentrated in the lower blocks, particularly those of *Podocarpus totara* G. Benn, ex D. Don. *Cupressus macrocarpa* and *Thuja plicata* D. Don. No significant weight losses were recorded in any of the *Eucalyptus* spp. exposed to the brown rot fungus.

Moisture Content of Test Blocks

When the test blocks were removed from the soil jars, the A blocks were generally drier than the B blocks. Two possible reasons for this are:

1. The B blocks had been decayed to a greater extent than the A blocks and, since one of the degradation products of cellulose is water, they would be expected to contain more moisture than the A blocks. It has been estimated that the cellulose in $1m^3$ of wood (0.50 sp gr.) rotted to 50% of its air dry weight would produce 139 l of water (Cartwright and Findlay, 1958). Thus in a 19 × 19 × 19 mm block similarly rotted the amount of moisture produced would be approximately 1 ml.
2. The B blocks being in direct soil contact, and hence direct moisture contact, might have initially absorbed more moisture than the A blocks and consequently reached a moisture content suitable for decay more quickly. Soil contact would also have tended to maintain a higher moisture content in the B blocks.

The latter reason appeared more plausible, and was examined in detail.

Materials and Methods

Soil jars were prepared in which the soil moisture content was adjusted to four different values: 90, 120, 150, and 170% WHC. This was achieved in two different ways.

(1) Water was added to the stock of soil until a moisture content of 90% WHC had been obtained. Some jars were filled with this soil. More water was added to the remainder of the soil to give a moisture content of 120% WHC. To obtain soil moisture contents of 150% and 170% WHC, water was added to the jars in amounts calculated to bring the overall soil moisture contents, when soil at 120% WHC was added, to the required values. The soil used to prepare these jars is referred to as "wet soil".

(2) Soil at 50% WHC (dry soil) was added to the required amount of water in the jars without mixing to bring the moisture contents to the same range of values as in preparation method (1). The method is similar to that described in ASTM D-2017 (ASTM, 1967a).

Half the soil jars at each moisture content prepared by each method were sterilised by autoclaving. *Pinus radiata* sapwood blocks were weighed at 12% e.m.c., sterilised by exposure to 1 : 2-expoxypropane vapour, and placed in jars using three different arrangements: (a) Blocks placed on feeder strips; (b) Blocks placed directly onto the soil surface; (c) "Double block" arrangement described above. The remaining half of the soil jars had the blocks added to them, in similar arrangements, before they were atuoclaved. Control jars containing blocks, but not soil, were used to determine possible atmospheric moisture absorbance during autoclaving and during incubation. Altogether three replicate jars at each moisture content, block arrangement, and soil preparation method were prepared. The jars were then incubated for 3 weeks at 27°C. This period

was chosen because, with inoculated jars, it would be the maximum time before growth of the decay fungus through the blocks would have begun to influence the moisture content of the blocks. After incubation, the blocks were removed from the jars and immediately weighed. They were then oven dried at 105°C, reweighed, and the moisture content at the termination of the experiment determined.

Results

The results are shown in Figs. 2-5. In these stereographs the final moisture content of the blocks has been equated to the two initial constants, soil moisture content and block position. The block position has been linearly arranged in order of increasing soil contact. Increase in weight of control blocks was negligible in all cases.

Figs. 2 and 3 show that when dry soil was used to prepare the soil jars (ASTM, 1967a) the overall soil moisture content had little influence on the moisture content of the test blocks when these were placed on feeder strips or in the A position. It was only in blocks that had been placed in the jars before autoclaving and were in direct soil contact that soil moisture content influenced that of the blocks. Similarly, when blocks were added to wet soil after autoclaving only those in soil contact (position B)

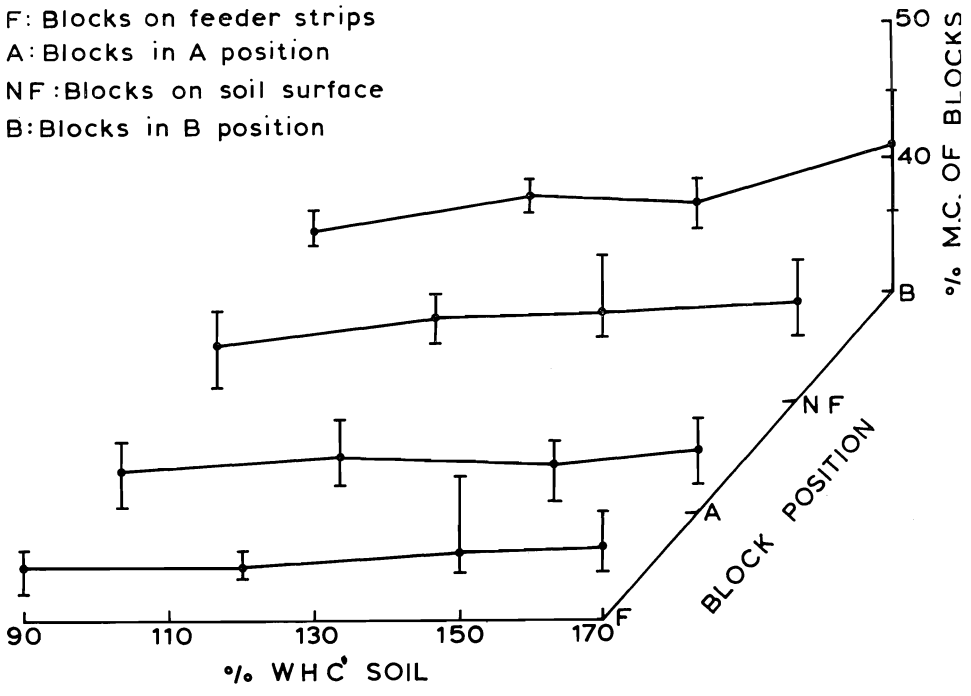

FIG. 2—Relationship between soil moisture content (m.c.), block position, and final moisture content of test blocks after 3 weeks' incubation. Dry soil was used to attain the different soil moisture contents. The blocks were added after autoclaving the soil jars.

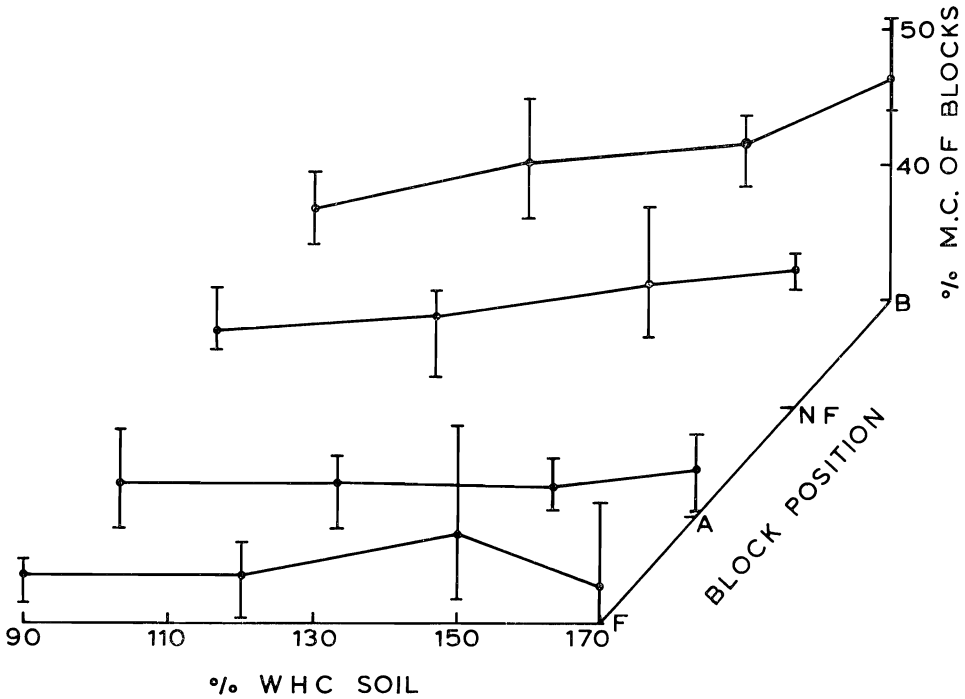

FIG. 3—Relationship between soil moisture content, block position, and final moisture content of test blocks after 3 weeks' incubation. Dry soil was used to attain the different soil moisture contents. The blocks were added before autoclaving the soil jars.

were influenced by the soil moisture content (Fig. 4). However, when the blocks were added to wet soil before autoclaving (Fig. 5), soil moisture content had an appreciable effect on block moisture content, particularly with blocks in direct contact with the soil. Thus, as illustrated in all four figures, blocks placed on feeder strips were little affected by soil moisture content, whatever its value. Blocks in the A position were affected only when autoclaved *in situ* in jars prepared from wet soil at a total soil moisture content of 170% WHC. It was only when the blocks were placed in contact with wet soil and autoclaved *in situ* that block moisture content was related to soil moisture content.

DISCUSSION

If a "double block" arrangement is contained in soil jars at 130% WHC prepared from wet soil, the moisture contents of the A and B blocks after 3 weeks' incubation would be 35% and 55% respectively. Although wood decay fungi vary in their minimum moisture requirements for decay (Cartwright and Findlay, 1958), Ammer (1964) gives 31% as the minimum moisture content of wood which would allow attack by decay fungi. Thus the A blocks, after 3 weeks' incubation, would be only slightly

above this moisture content. It is suggested that the reason for the disparity in attack by the decay fungi is the difference in moisture content attained by the A and B blocks. That this disparity varied between species of timber and species of fungi may be because of variation in permeability of the timbers to available moisture and also variation in the tolerance of the fungi to different timber moisture levels. With a permeable softwood (*Pinus radiata*) sapwood subjected to attack by *Lenzites trabea* (brown rot), both A and B blocks reached a moisture content of 35% or above, suitable for attack by this fungus. However, the heartwood species tested had lower permeabilities and the optimum moisture content for decay was only attained in the B blocks. *Eucalyptus* spp. were not susceptible to decay at any moisture content. Why B blocks of *Populus robusta* were decayed to a greater extent than the A blocks, cannot be explained on the basis of moisture relations alone, since this timber is also very permeable. A knowledge of factors other than moisture relations would be required to explain the differences in attack by brown rot fungi on *Pinus radiata* sapwood and *Populus robusta* sapwood.

White rot fungi, however, evidently require for attack relatively high moisture contents which are only achieved in the lower (B) blocks, even in permeable timbers.

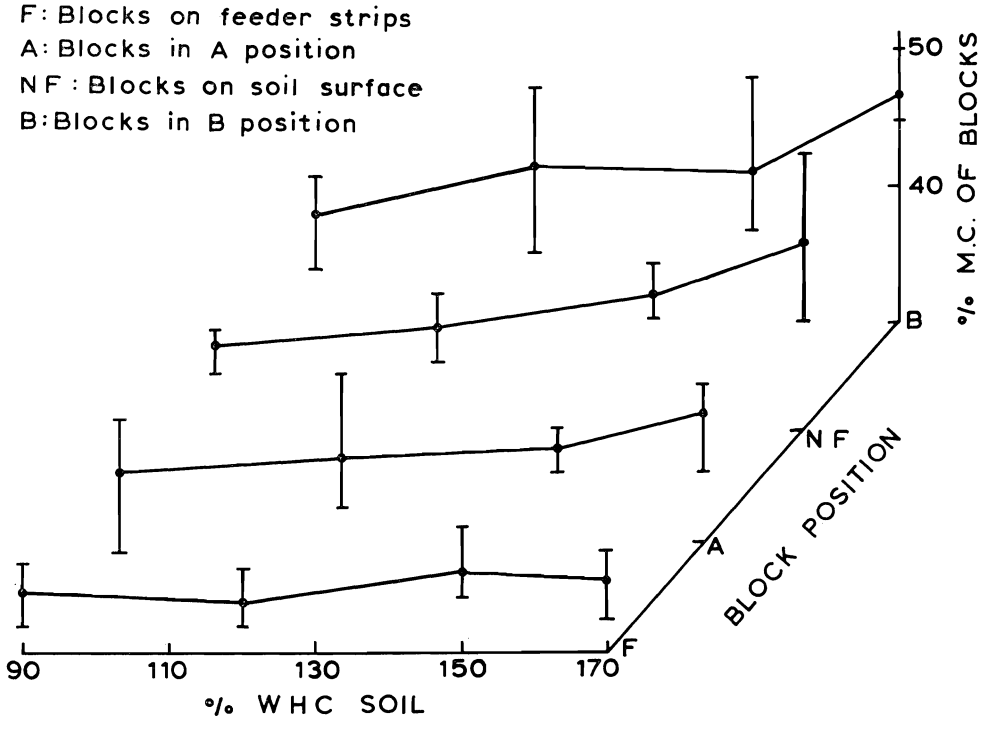

FIG. 4—Relationship between soil moisture content, block position, and final moisture content of test blocks after 3 weeks' incubation. Wet soil was used to attain the different soil moisture contents. The blocks were added after autoclaving the soil jars.

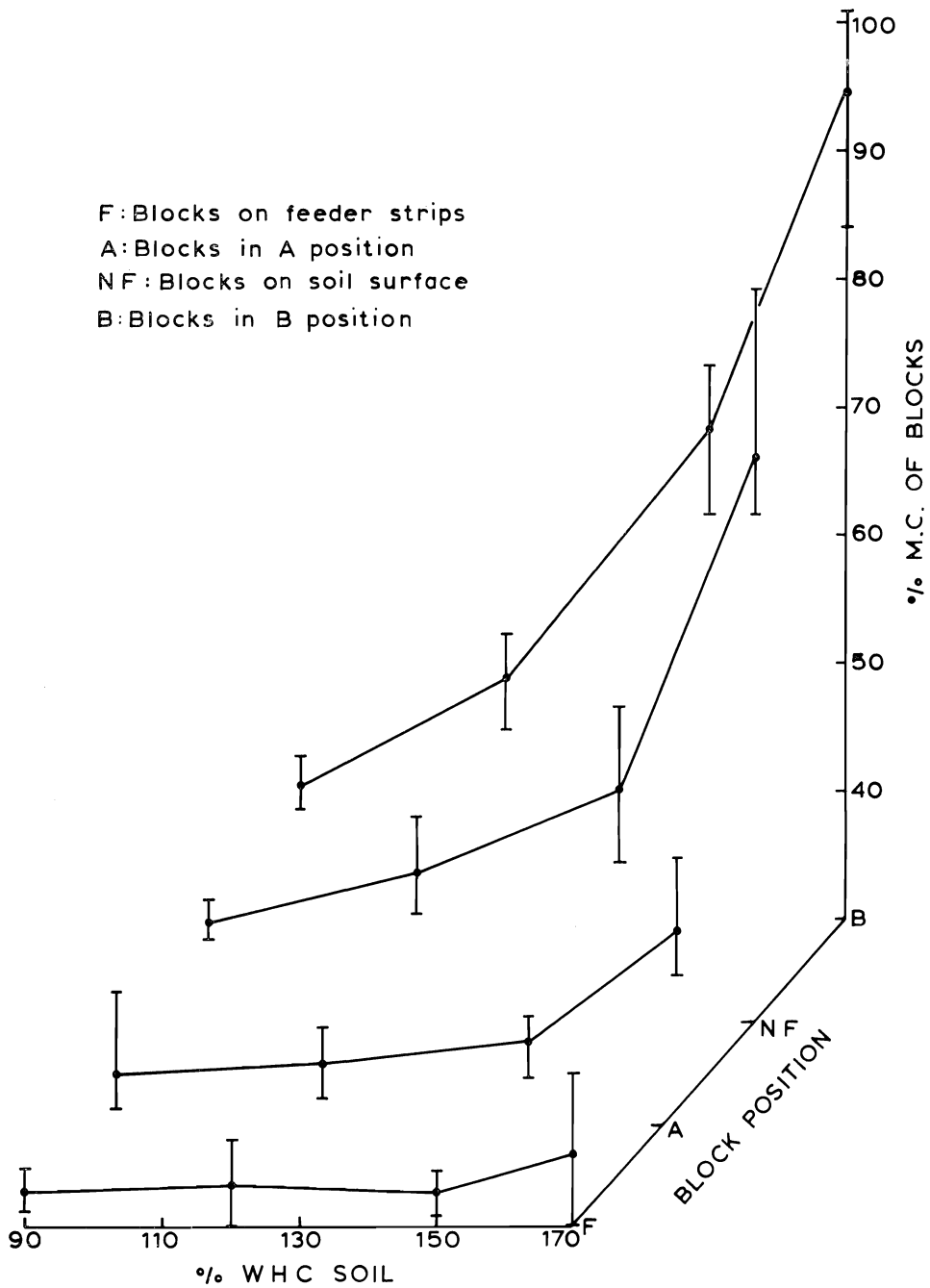

FIG. 5—Relationship between soil moisture content, block position, and final moisture content of test blocks after 3 weeks' incubation. Wet soil was used to attain the different soil moisture contents. The blocks were added before autoclaving the soil jars.

CORRELATION WITH FIELD RESULTS

In the ASTM standard for determining the natural durability of timber (D-2017) the timber may be rated according to weight losses sustained by the test blocks (Table 3). If the timber species in Table 2 are tested for their natural durability by the standard method, which is essentially the same as the double block technique without the lower block, they would almost invariably be assigned a decay resistance class higher than justified. This is an important consideration, for the prime value of laboratory tests is their ability to predict field performance.

TABLE 3—ASTM ratings for particular weight losses of test blocks

Decay resistance class	Mean % weight loss
1. Highly resistant	0.10
2. Resistant	11-24
3. Moderately resistant	25-44
4. Non resistant	45+

In Table 4 the decay resistance classes, to which the timbers listed in Table 2 can be assigned, are compared with results from field tests on 19 x 19 x 407mm stakes of the same species of timber. Field results are expressed as the percentage number of stakes remaining after 5 and 9 yr in the ground. A stake is recorded as failed if it breaks under moderate hand pressure. Also recorded are the length of time for 50% of the stakes to fail, and a provisional durability rating based on Purslow (1962). More than 50% of *Podocarpus totara* and *Eucalyptus pilularis* stakes remain sound after 9 yr.

TABLE 4—A comparison of the natural durability ratings obtained with laboratory tests using 19 × 19 × 19 mm blocks and field tests using 19 × 19 × 407 mm stakes

Timber species	Laboratory resistance class		% stakes remaining after		Time to 50% failure	Provisional durability class from stake test
	A blocks	B blocks	5 yr	9 yr		
Podocarpus totara	Highly resistant	Highly resistant	100*	100	NR	Very durable
Eucalyptus pilularis	" "	" "	97*	58	NR	" "
E. botryoides	" "	Resistant	75†	35	7	Durable
E. saligna	" "	"	65†	21	7	"
Cupressus macrocarpa	" "	"	40‡	0	4-5	Mod. durable
Sequoia sempervirens	Mod. resistant	Non resistant	0‡	0	4	Non durable
Thuja plicata	Resistant	" "	0‡	0	3	" "

* Results from 30 stakes.
† Results from 40 stakes.
‡ Results from 10 stakes.
NR = not reached.

Table 4 shows that the results from B blocks correlate much better with the field results than do results from A blocks. The former are therefore much more useful than the latter in indicating performance of the timber in ground contact.

CONCLUSIONS

The ASTM standard soil/block method is not the most suitable for obtaining optimum weight losses in test blocks, particularly when a white rot fungus is used as the decay organism. Highley and Scheffer (1970a, 1970b) also concluded that the ASTM standard method gave less than satisfactory results with white rot fungi. They achieved higher weight losses by supplementing the soil with nutrients and substituting filter paper for the feeder strip; neither modification is necessary with the "double block" technique described here.

A further advantage of this technique is that it allows a comparison to be made between timber in a high decay hazard situation (B block) and timber in a relatively low decay hazard situation (A block). Since the position of the A blocks in the jars is virtually the same as blocks in the standard technique, results from them could be readily equated to results from previous investigations using the standard technique.

It is therefore suggested that all future laboratory investigations on the natural durability of timber should be done using the "double block" technique.

REFERENCES

AMMER, U. 1964: On the connection between moisture content and fungal decay in wood. **Holz als Roh-und Werkstoff, 22:** 47-51.

ASTM, 1967a: Accelerated laboratory tests of natural decay resistance of woods (D-2017). Page 682 of part 16 **in** "1967 Book of ASTM Standards". American Society for Testing and Materials, Philadelphia.

ASTM, 1967b: Wood preservatives by laboratory soil-block cultures (D-1413). Page 190 of part 16 **in** "1967 Book of ASTM Standards". American Society for Testing and Materials, Philadelphia.

BS, 1961: "Methods of test for toxicity of wood preservatives to fungi" (BS838). British Standards Institution, London.

DUNCAN, C. G. 1958: Studies on the methodology of soil-block testing. **Forest Service, United States Department of Agriculture, Forest Products Laboratory Report 2114.**

CARTWRIGHT, K. St G., and FINDLAY, W. R. K. 1958: "The decay of timber and its prevention." Her Majesty's Stationery Office, London.

HIGHLEY, T. L., and SCHEFFER, T. C. 1970a: Natural decay resistance of 30 Peruvian hardwoods. **Forest Service, United States Department of Agriculture, Research Paper FPL 143.**

——— 1970b: A need for modifying the soil-block method for testing natural resistance to white rot? **Material und Organismen, 5 (4):** 282-92.

LEUTRIZ, J. 1939: Acceleration of toximetric tests of wood preservatives by the use of soil as a medium. **Phytopathology 29:** 901-3.

——— 1946: A wood soil contact culture technique for laboratory study of wood destroying fungi, wood decay, and wood preservation. **Bell Systems Technical Journal 25:** 102-35.

PURSLOW, D. M. 1962: The effect of specimen size on the life of timber in contact with the ground. **Wood 27:** 99-100.