Decay in mine timbers. Part I. Sampling procedures and conditions and descriptions of samples

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Abstract

To aid in the prevention of mine accidents, timber framing must be regularly inspected for decay. It is necessary to first develop a means of assessing the condition of timbers and determining their strengths. From 18 coal mines in Pennsylvania, West Virginia, Illinois, Alabama, Utah, and Colorado 430 timbers were removed for sampling. Timbers were predominantly oaks and maples (Pa. and W. Va.), oaks and sweetgum (Ill.), southern pines (Ala.), and lodgepole pine (Colo. and Utah). They were generally round and non-preservative treated, and still retained their bark or remnants of it. White rot predominated in hardwood timbers collected in Illinois, Alabama, and West Virginia. In the Pennsylvania mines a rather even distribution of white and brown rot was evidenced; many timbers contained mixtures of white and brown rot. In softwood timbers from all mines only brown rot was visible. Moisture conditions and, hence, decay frequency varied widely both between mines and within a given mine. Where intake and return air courses were sampled in a given mine, both humidity and temperature were highest in the return.

In **1975,** nearly **290** million tons of coal were produced in the United States, requiring **1.3** board feet of sawed timber and **0.5** linear foot of round or split props for each ton of coal mined (13). Timbers are largely used in mines as roof strata supports and as haulage track ties. Wood mine supports have numerous advantages over those of other materials. Timber is relatively abundant and inexpensive, it possesses great strength in relation to its weight, and it can be cut and framed easily (3). Wood tends to bend and "talk" before collapse, thus telegraphing dangerous roof conditions (3). Its major weakness is its susceptibility to decay when used under conditions favorable to growth of wood-rot fungi.

Unfortunately, conditions in mines generally are very favorable to decay (3); temperature, air supply, and damp atmosphere of mines favor fungal growth (7). Attesting to these conditions are the low service life averages attributed to untreated mine timbers: 3 years (3), 3 to 5 years (7), 1+ to 3 years for loblolly (*Pinus taeda* L.) and shortleaf (*P. echinata* Mill.) pines (10), 19 to 32 months (14), 2 to 4 years (2), and 2 years for mine ties (6).

The widespread failure of mine timbers due to decay results not only in large monetary losses but, more importantly, may result in injury or death to miners. In 1949, roof falls accounted for over half of all fatal underground mine accidents; almost a quarter were due in some measure to decayed track ties (3). In 1978, 73 lives were lost in underground coal mines, the major cause of deaths - 31 - being roof falls (1). In addition to problems with roof fall, decayed timbers ignite readily and burn rapidly creating greater fire risk in the mine (3, 9). To aid in the prevention of roof accidents, it is essential that mine timbers be regularly inspected for signs of decay. For this purpose, a reliable means of assessing the condition of timbers and determining their strengths needs to be developed.

In 1978, an interagency research agreement was entered into by the Bureau of Mines and the Forest

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Products Laboratory (FPL), the main objective of which was to develop a device or method for determining the *internal* condition of mine timbers relative to incidence and amount of decay and, hence, the "residual" (present) strength. Some changes in these objectives evolved, however, once the study was initiated and knowledge of the onsite mine timber decay problem grew. Because of the extensive use of untreated timbers, decay in mines was largely associated with timber exteriors, rather than interiors. This necessitated changes in our approach to methodology of timber strength determinations. The summation of this work is presented in three parts:

1. Sampling procedures and conditions and description of samples.
2. Basidiomycetes associated with coal-mine timber decay.
3. Species-independent stress grading.

This publication deals with Part I.

Methods

Field investigation

Because of the source of financial support, only coal mines were visited in these studies. Attempts were made to sample coal mines located in all the coal-producing sections of the United States. Choice of individual coal mines within a given region, based upon availability of timber samples desired and anticipated cooperation of the mine superintendents, was left to the discretion of local Mine Safety and Health Administration (MSHA) personnel. In all, 18 mines were sampled: 4 in Pennsylvania, 5 in West Virginia, 3 in Illinois, 2 in Alabama, 2 in Utah, and 2 in Colorado.

Within a given mine, we generally proceeded to the wetter areas, where decay could be expected to be most prevalent, and attempted to locate suitable timbers for retrieval. For obvious reasons no standing timbers were removed. Timbers were collected from those lying scattered throughout the traversed passageways, where they had been placed following their removal from use. Only timbers having a minimum diameter at the small end of 10.2 cm (4 in.) and a minimum length of 106.7 cm (42 in.) were generally sought for sample inclusion. Where suitable timbers were plentiful, attempts were made to obtain sample timbers ranging in condition from sound to moderately decayed for use in comparative strength tests. In some cases, short pieces of badly decayed wood were collected for fungal isolation purposes only. Dry- and wet-bulb temperatures were taken, usually in the vicinity of appreciable sample collecting, and relative humidities (RH) were calculated. Also, our position in the mine relative to depth and type of airway was normally recorded.

Upon removal of timber samples from a given mine, they were individually numbered. Increment borings, or disks, were removed from a number of them and placed into plastic bags for future moisture content (MC) determinations. The timbers were then shipped to the FPL for study. A total of 430 timbers were collected from the 18 mines.

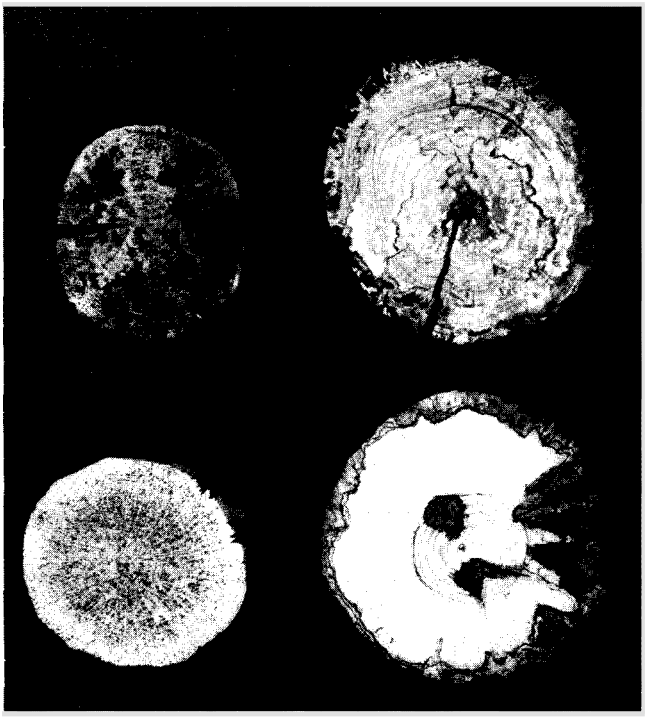

Figure 1. - Decay types in hardwood mine timbers. Clockwise from lower left: white rot, brown rot, white and brown rot, and brown and white rot.

Laboratory investigation

The borings and disks obtained in the field were weighed and ovendried at 105°C for 24 hours. When dried, they were reweighed and their MCs were calculated. This information was gathered for later use in strength tests. When the timbers arrived at the Laboratory, they were stored at 2.2°C (36°F) until testing, when they were debarked and their ends were squared to form 0.91-m (3 ft.)-long samples. The ends were examined and the presence or absence of decay was determined and, where present, the decay type was noted.

Decay types (Fig. 1) included white and brown rot, both of which are considered "typical wood decay" and are caused by basidiomycetes, and soft rot, a decay caused by nonbasidiomycetous fungi - i.e., ascomycetes and imperfect fungi - and mixtures of these. Portions of the ends were then used for identification of tree species and for isolation of fungi. Isolation techniques are described in Part II of this series.

The timbers were returned to the cold room until removed for nondestructive- and destructive-type testing. These techniques are described in Part III.

Results and discussion

Environmental conditions in mines have generally been considered to be conducive to timber decay (3, 7). However, within and between individual mines, conditions affecting severity of decay may differ widely.

TABLE 1. - *Temperature and humidity conditions in mines, near sampling areas.*

State	Mine	Mine level	Mine ventilation	Month	Temperature	Relative humidity
		(ft.)			(°F)	(%)
Pennsylvania	Newfield	325-350	—	September	58.0	94
	Newfield	325-350	—		62.5	97
	Clyde	300	Return	October	54.6	89
	Clyde	300	Return		58.0	91
	Banning	280	Neutral	November	48.8	73
	Banning	—	—		55.5	73
	Russelton	225	Intake	November	49.7	75
	Russelton	Track entry	Neutral		52.0	85
West Virginia	Williams	500	Intake	March	51.5	77
	Badger	—	—		56.2	93
	Skeleton	600	Intake	April	55.0	88
	Quinnwood	80	Neutral	April	52.0	87
	Quinnwood	Track entry	Neutral		50.0	93
Illinois	Orient	796	Return	April	67.5	74
	Orient	796	Intake		53.0	52
	Sahara	240	Intake	April	65.0	80
	Wabash	800	Return	April	60.0	77
	Wabash	Track entry	Neutral		65.0	66
Colorado	Bear	700	Return	April	64.3	79
	Bear	1,700	Intake		50.0	55

Temperatures vary according to mine passage level - high temperatures exist at lower levels and vice versa (4, 14) - which affects timber longevity. In one mine, untreated timbers on upper levels, where the air temperatures were less than 50°F, retained their strength for 10 + years. At lower levels, where temperatures ranged up to 62°F and the RH was almost 100 percent, fir and spruce timbers lasted for only about 4 years (9).

Moisture and temperature within a given section of a mine are influenced by the direction of airflow - i.e., entering air ("intake") or exhaust air ("return"). Return air picks up moisture and warmth as it progresses through the mine (8). As it encounters cooler conditions at upper levels, moisture condenses on rock and timbers. Timbers exposed to return air generally have more decay and shorter service life than those in the intake courses. Oak timbers exposed for 18 months in the return airway of a mine lost 10 percent more crushing strength than oak placed in the intake course for a similar period (12). In another mine, timbers were reported to last only 6 to 8 months in the return (5).

Temperature and RH in those portions of the mines sampled were recorded. Where return and intake courses were sampled within a given mine (Orient and Bear Mines, Table 1), both temperature and RH were higher in the return. Large differences were noted between mines, some being humid throughout with walls and timbers covered with water droplets and others so dry as to make difficult the search for decayed timbers. Within individual mines, also, humidity and decay varied greatly.

Frequency of utilization of different tree species for mine timbers was recorded (Table 2). In the Pennsylvania, West Virginia, and Illinois mines, hardwood timbers predominated: white and red oaks, maples, hickories, and cherries were most abundant in Pennsylvania; white and red oaks, maples, and yellow-poplar in West Virginia; and red oaks and sweetgum in Illinois (Table 2). In Alabama mines, southern pine was most plentiful, although a scattering of hardwood timbers was also collected. In the western mines only one hardwood (aspen) was collected; other timbers were largely lodgepole pine and some western spruce (Table 2).

Most of the timbers collected were round with their bark intact. Except for one round timber and some squared ones, they were not preservative treated. Because sapwood, which is more susceptible to decay than heartwood, was plentiful on the timbers sampled, exterior decay or at least decay originating in the exterior predominated. Where interior decay was present, as was the case in a number of black locust and white oak timbers, it was assumed to have originated in the living tree.

The type of degrade present was affected primarily by wood type - i.e., hardwood or conifer (Table 3) - and, to a lesser degree, by mine locale. Overall, white rot predominated in hardwood timbers collected in Illinois, Alabama, and West Virginia. This was expected as hardwoods in use aboveground have long been known to be particularly prone to attack by white-rot fungi.

In the Pennsylvania mines, a fairly even distribution of white-rot and brown-rot attack was evidenced. Many of the timbers contained a mixture of the two types of rot (Table 3, Fig. 1). This is often found in fence posts in ground contact where hardwoods or softwoods are commonly attacked by both brown- and white-rot fungi (11). The factors responsible for the prevalence of brown rot in hardwood timbers in the Pennsylvania mines are not known. Soft rot was present in noticeable amounts in only three hardwood timbers: two from Alabama and one, in association with white rot, from West Virginia (Table 3).

In coniferous timbers from all mine regions, only brown rot was encountered (Table 3). However, five timbers from a Utah mine, which contained an orange-colored decay, were included in the brown-rot grouping

TABLE 2. — *Frequency of timber types, by locale, from 18 coal mines.*

Tree species	Pennsylvania	West Virginia	Alabama	Illinois	Colorado	Utah
			HARDWOODS			
White oak	27	36	5	6	0	0
Maple	28	25	0	1	0	0
Red oak	24	13	2	14	0	0
Hickory	14	5	3	3	0	0
Cherry	22	2	0	0	0	0
Yellow-poplar	2	13	1	2	0	0
Sweetgum	0	0	2	13	0	0
Black locust	2	10	0	0	0	0
Ash	5	4	0	1	0	0
Sassafras	2	4	0	0	0	0
Other[a]	9	7	1	2	1	0
			CONIFERS			
Lodgepole pine	0	0	0	0	19	47
Southern pine	0	0	35	0	0	0
Western spruce	0	0	0	0	9	3
Red pine	3	0	0	0	0	0
True fir	0	0	0	0	1	1
Eastern hemlock	1	0	0	0	0	0
Totals	139	119	49	42	30	51

"Includes aspen, magnolia, birch, elm, etc., each of which was collected fewer than five times.

TABLE 3. - *Type of degrade encountered in mine timber samples from different locales by frequency.*[a]

Degrade type[b]	Pennsylvania	West Virginia	Alabama	Illinois	Colorado	Utah
			HARDWOODS			
White rot	39(30)	54(52)	9(69)	30(100)	—	—
White plus brown	16(13)	12(12)	0	0	—	—
White plus soft	0	1(1)	0	0	—	—
Brown rot	36(28)	18(17)	1(8)	0	—	—
Brown plus white	36(28)	19(18)	1(8)	0	—	—
Soft rot	1(1)	0	2(15)	0	—	—
			CONIFERS			
Brown rot	1(100)	—	29(100)	—	9(100)	38(100)

[a]Frequency and percentage of total frequency (in parentheses) of encounter of decay types or combinations of types.
[b]Where combinations of degrade are present, the predominant one is listed first.

although it is not certain that this decay is brown rot. The presence of brown rot in softwoods used aboveground was expected from past observations (11). Soft rot was not noticeable in any of the softwoods sampled.

Summary

The study of decay in mine timbers was initiated primarily for the purpose of developing a means of assessing the condition and strength of these timbers in situ. To aid in attainment of this goal 430 timbers were collected for study from 18 coal mines located in five states. The present report, which is the first in a series of three, identifies the tree species used for coal mine timbers within various sections of the United States and characterizes the types of decay associated with each. A discussion of environmental conditions in mines, together with their effect upon severity of wood decay, is included.

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