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APPARATUS FOR DURATION OF LOAD COMPRESSION TESTS OF DIMENSION LUMBER

by

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SUMMARY

This study is part of a larger research program aimed at assessing the effect of long-term loading on the behavior of 2- x 4-in. spruce lumber in compression parallel to grain. This report describes the development of a testing apparatus for long-term constant loading of 2- x 4-in. dimension lumber in compression parallel to the grain. The machine is designed for a load capacity of 20,000 lb. The load is produced by a mechanical loading system consisting of a dead weight and a lever system with a mechanical advantage of 70:1.

Tests conducted with a prototype model revealed that over the long-term, an applied load can be maintained within a variation of ± two percent. The cost of manufacturing one unit was found to be Can. $608.00.

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OBJECTIVES

The general objective of the research program is to determine the effect of long-term loading on the creep-rupture behavior of white spruce, 2- x 4-in. dimension lumber, in the compression mode. The specific objectives of this phase of the research program were:

1. To design a long-term compression test machine for 2- x 4-in. lumber;

2. To build one prototype machine;

3. To assess the performance of the prototype.

INTRODUCTION

The adjustment factor for duration of load is one of the largest adjustment factors applied to the short-term strength properties of lumber to obtain design stresses. The adjustment factors currently used have been derived from tests on small, clear bending specimens. The factors have been applied without verification to derive design stresses for full-size lumber and other wood products, for different species and failure modes.

New research on duration of load effects for lumber in bending revealed that the constant load versus time-to-failure relationship for full-size lumber differs from that derived for small, clear specimens. This indicated a need for further research. A high priority was given to the evaluation of duration of load effects in compression parallel-to-grain of 2- x 4-in. spruce lumber.

BACKGROUND

During the last 10 years, a considerable research effort has been devoted to studying duration of load effects in bending (Samson, 1983, 1984) and tension parallel to grain (Barrett, 1983; Glos and Barrett, 1979) for dimension lumber. However, no research has been performed in North America to evaluate duration of load effects in compression parallel to grain for full-size dimension lumber. Furthermore, insufficient consideration has been given to development of testing equipment suitable for large scale compresssion duration of load projects.

The objectives of long-term experiments differ from those of short-term testing and, therefore, the design of a long-term testing apparatus must recognize the special features of the experimental program, namely, (1) the basic long-term experiment is the constant load test in which specimens are loaded at a constant rate until a predetermined stress level is reached; (2) the stress level must be held constant over a period of several years.

Because of the long duration of each individual test, it is necessary that testing equipment be available to allow simultaneous testing of many specimens. When many frames are required, the cost per frame becomes critical. Therefore, total cost of appropriate long-term testing apparatus must be kept to a minimum.

The design of the long-term testing apparatus reduces to two main problem areas: (1) to develop a system for laterally supporting the specimen to prevent buckling over a long period; (2) to develop a method of maintaining a defined load on the specimen over the same period of time. The design load is determined by the intended maximum level of stress, which will normally be a fraction of the ultimate short-term strength of the lumber to be tested.

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METHODS AND RESULTS

DESIGN REQUIREMENTS

The basic requirements governing the design of the apparatus included:

- the apparatus should be adequate for testing lumber with a nominal thickness of two inches, a width of up to four inches and a total length of up to 63 inches;
- the load capacity should be 20,000 lb., which allows 2- x 4-in. specimens to be loaded to 3,800 psi;
- the apparatus should allow a specimen to be loaded and unloaded easily;
- the apparatus should allow for adequate lateral support of the specimen;
- within the duration of the test, the load applied on the specimen should be kept to the intended value as closely as possible;

- the apparatus should be suitable for adapting a time-to-failure monitoring system and a system for measuring specimen deformation under constant load;

- the total cost should be kept to a minimum.

DESCRIPTION OF PROTOTYPE COMPONENTS

The duration of load compression testing prototype is illustrated in Figure 1. The machine consists of the following principal components described schematically in Figure 2:

- a frame;

- a loading head;

- devices for load application;

- devices for recording time-to-failure and specimen deformation.

Individual components are described in the following sections.

The Frame

The frame stands vertically and is fastened to the floor at the base. Essentially, the frame consists of three parts: the space frame, the lateral supports and the end reaction.

The space frame consists of four steel angles 2- x 2- x 3/16-in. braced at regular intervals. Braces seen on the side view in Figure 1 are welded to the frame, whereas those on the front view are bolted braces which can be removed when loading a specimen into the frame. During testing, the space frame is loaded in tension.

In the frame, the specimen is prevented from buckling laterally by a series of roller supports. Spacing between lateral supports is such that the slenderness ratio (length over least radius of gyration, based on a 1-1/2 x 3-1/2 in. rectangular cross-section) does not exceed 17. The distance between the support rollers is six inches on the wide face and 11 inches on the narrow face of the specimen. The lateral supports are bolted onto the main frame allowing the gap between the specimen and the supports to be set to any desired value.

A one inch steel plate, bolted between the four angles near the base of the frame, is used as end reaction. The specimen does not rest directly on the bottom plate but rather sits on a compression plate (2- x 4- x 1/2-in.) separated from the bottom plate by a spherical thrust washer. This arrangement ensures uniform bearing of the specimen and eliminates misalignment problems.

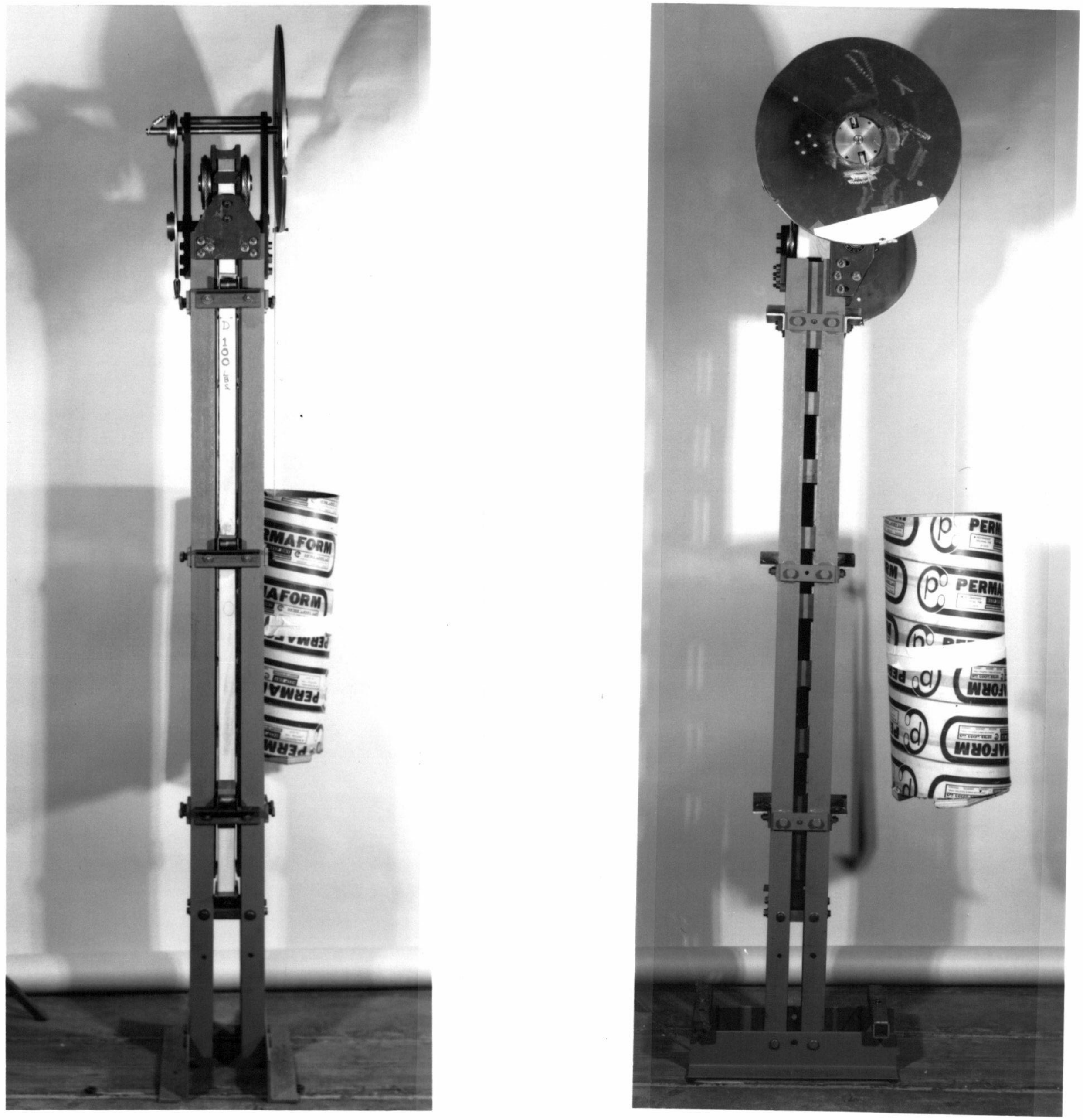

Figure 1. General View of the Compression Testing Apparatus.

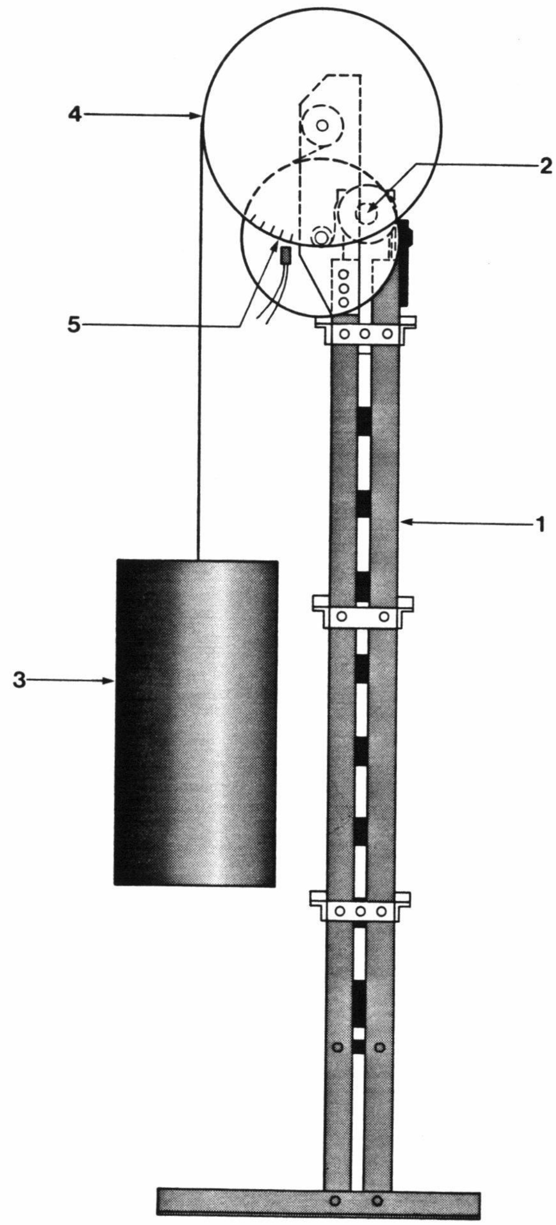

Figure 2. Components of the Testing Apparatus:
1. frame, 2. loading head, 3. dead weight,
4. mechanical level system, and 5. time-to-failure and deformation recording devices.

The Loading Head

The load is applied at the top of the specimen by means of a loading head having the shape of a small cage, illustrated in Figure 3. The load is transmitted to the head via two 5/16 inch cables connected to the mechanical lever system. The cables run in two pulleys mounted on opposite sides of the cage. The cage can rotate relative to the pulleys to ensure uniform bearing on the specimen. The loading head was designed to allow easy and rapid insertion of the specimen in the testing apparatus.

The Loading System

The mechanical loading system consists of a dead weight exposed to the influence of gravity and a lever system with a mechanical advantage of approximately 70:1. Consequently, a dead weight of 285 lb. is required to produced a compression load of 20,000 lb.

The lever system consists of a set of three pulleys with diameter ratios of roughly 6:1, 6:1 and 2:1. All the pulleys are mounted on shafts with ball bearings. For transferring load across the pulleys, high strength steel cable is used.

Time-to-Failure and Deformation Recording Devices

Displacement of the loading head can be used to record deformation of the specimen during testing. This deformation can be sub-divided as follows: (1) deformation resulting from application of the dead weight, (2) deformation due to creep, and (3) deformation resulting from failure of the specimen. Time-to-failure is recorded while this last deformation component takes place.

Both loading and creep deformations, as well as time-to-failure, can be measured by monitoring the movement of the dead weight whose displacement is approximately 70 times greater than that of the loading head. Dead weight displacement is more conveniently measured on the circumference of the large pulley.

As shown in Figure 4, creep and time-to-failure are measured using a series of electronic contacts located on the periphery of the large pulley. Each of these contacts is wired to a microcomputer which records the exact time at which the contact closes. These contacts, located one inch apart on the pulley circumference, will record displacement of the loading head at every 1/70-inch increment.

PERFORMANCE ASSESSMENT

Several tests were conducted on the prototype testing machine with 2- x 4-in. white spruce dimension lumber to evaluate friction in the system and ability of the machine to maintain a constant load on a specimen over a long period of time.

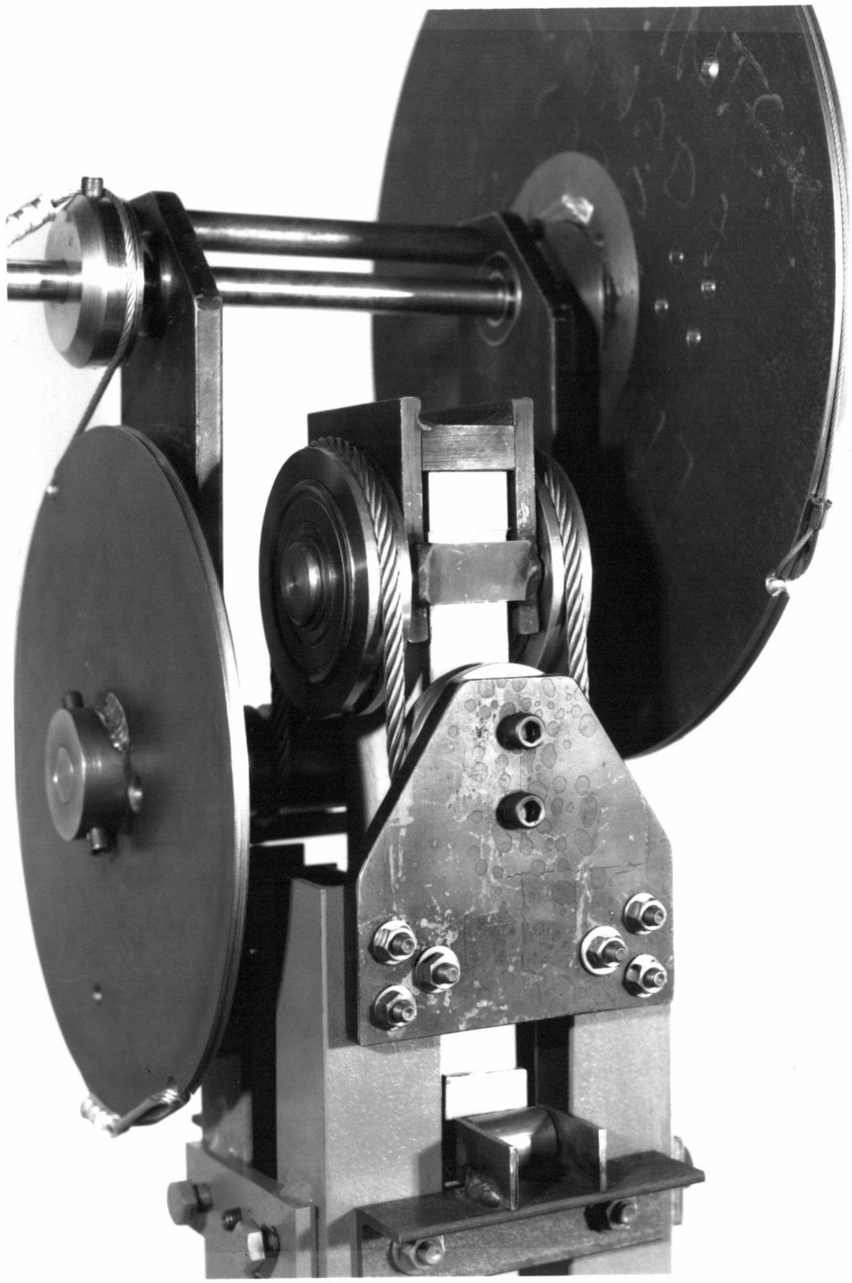

Figure 3. Details of the Loading Head.

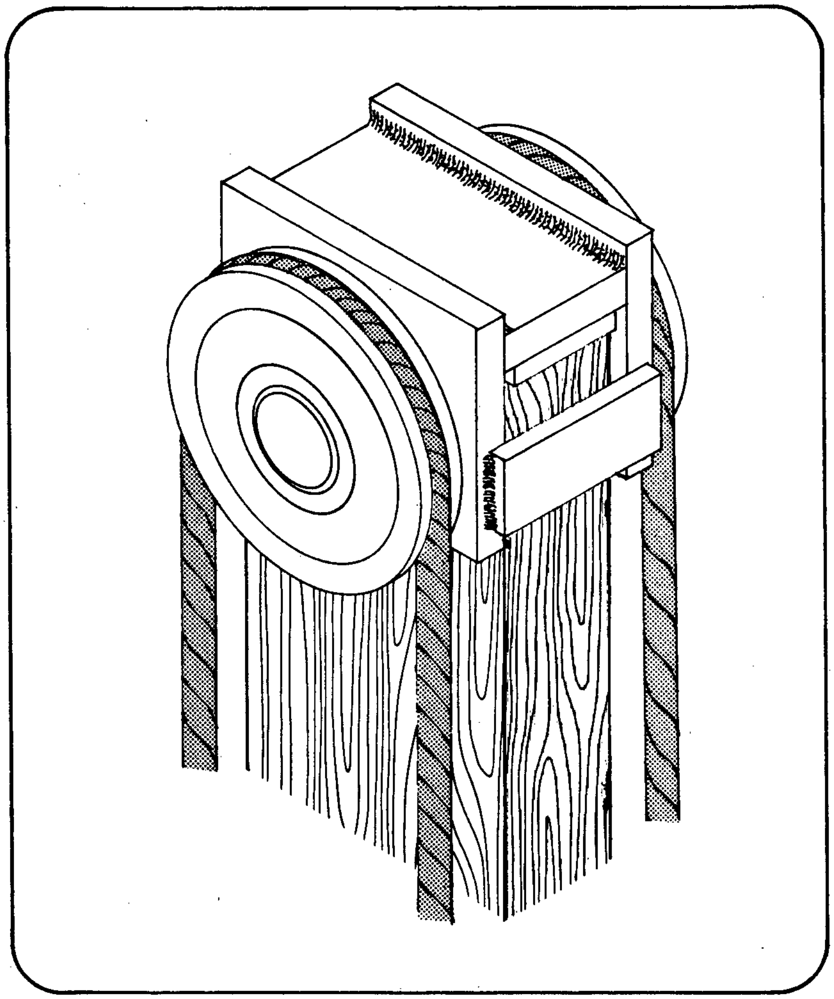

Figure 4. Further Details of Loading Head

The overall internal friction in the mechanical loading system is determined mainly by the bearing friction between pulleys and shafts and by the cable internal friction. Bearing friction between lateral support rollers and the test specimens was found to be negligible.

Tests undertaken to assess testing machine performance were conducted using various dead weights (from 90 lb. to 200 lb.), under various creep rates and for various durations (from five hours to five days). Results indicate that, over the long-term, an applied load can be maintained on the specimen within a variation of ± two percent, independent of load level and creep rate, as long as the direction of motion of the dead weight is not reversed. If the direction of dead weight motion is reversed, due to non-constant loading history or extreme climatic changes, then, a change of the applied load of up to four percent can arise due to effects of friction.

COST

The cost of building the testing apparatus described depends on the number of units to be manufactured. The cost of manufacturing 100 units in Vancouver, B.C., in the first quarter of 1985, was found to be Can. $608.00 per unit. The cost breakdown is as follows:

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Material	
Structural steel--100 lb. @ $0.50/lb.	50.00
Pulleys, hubs and shafts--40 lb. @ 1.00/lb.	40.00
Bolts	25.00
Roller lateral supports	105.00
Bearings	100.00
Cables and dead weight	40.00
	$360.00
Labor	
Machining shafts, pulleys, hubs and loading head - six hours @ $16.00/hr.	96.00
Fabricating main frames and lateral guides - eight hours @ $16.00/hr.	128.00
Assembling and erecting frames - two hours @ 12.00/hr.	24.00
	$248.00
TOTAL	$608.00