IN-SERVICE INSPECTION OF UTILITY WOOD POLES USING THE VIBRANTE TESTING TECHNIQUE

by

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INTRODUCTION

North American utilities spend over $4 billion each year on wood pole replacement programs.(1) Utilities continue to rely on unsophisticated and inaccurate test methods to identify poles in need of repair or replacement. Most utilities and inspection companies use sounding and coring methods to locate decay. While this procedure is probablyt he best existing methods, it has severe limitations.

Recognizing this problem, B.C. Hydro, with the support of the Canadian Electrical Association, developed a new, more accurate method of inspecting wood poles based on using modal analysis as a test parameter. One advantage of this type of analysis is that the entire pole can be examined by a single measurement in contrast to other methods that examine only specific sections of a pole.

OTHER POLE INSPECTION METHODS

The most commonly used inspection method, sounding and coring, consists of hammering a pole near the ground line and listening for hollow sounds. If such sounds are detected, core samples are examined in an attempt to establish the magnitude of the defective region.

One of the most obvious limitations of this method is that it relies heavily on the expertise of the inspector. Both the sounding test and the examination of core samples are very subjective, but there are also other, less obvious problems with these tests. For example, the coring tests are not entirely non-destructive since material is removed from the pole. The coring tool can also introduce decay bacteria into wood which was previously uncontaminated.

Much research has been done with the aim of identifying some readily measurable parameter, such as sound velocity through the material, sound adsorption, or material resonance, to determine one or more wood strength properties.(1-5) Although elaborate claims are made for many of these methods, each approach has inherent limitations. Because these methods examine specific cross sections, several tests are required to fully inspect each pole. Also, soil excavation is required to examine that portion of a pole below the ground. This greatly increases the overall cost associated with each inspection.

ANALYSIS TECHNIQUE

Through a Canadian Electrical Association research contract, B.C. Hydro developed a test method that predicts a pole's stiffness and strength (6-9) and overcomes the aforementioned limitations. The method, called Vibrante (Vibration Analysis Testing), involves tapping the pole with a rubber mallet to identify its structural resonant frequencies. These frequencies are subsequently used in a mathematical model to determine the relative stiffness or strength of the pole.

The theory can be illustrated by comparing the response of a sound pole with that of a pole containing a large defect near the ground line (Figure 1). If each pole was tapped with a rubber mallet, the poles would vibrate at different frequencies. The new pole would vibrate quickly because the strong ground line would impart a large restoring force. The weak pole, in contrast, would vibrate somewhat more slowly as the weakened ground line material would impart a much smaller restoring force. The same vibration patterns would also be expected in the mathematical equivalents of these poles (also shown in Figure 1).

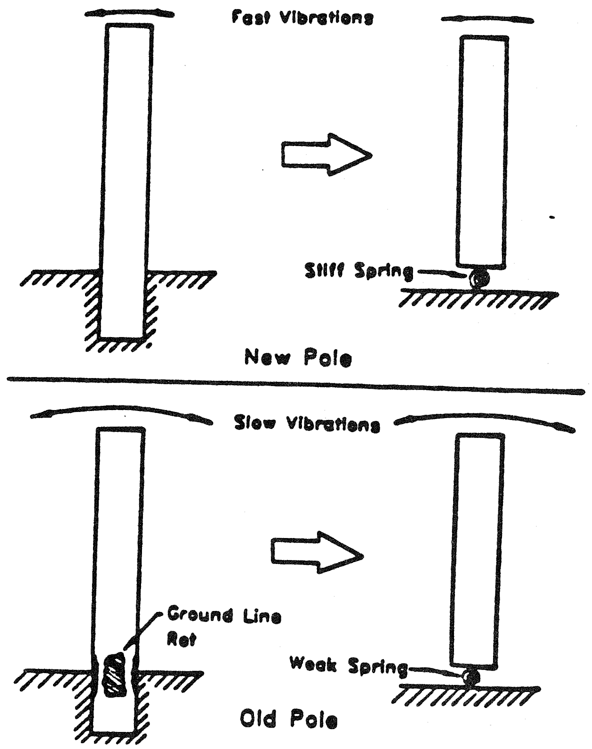

Figure 1: Vibrations of a New and Old Pole

The complete mathematical model consists of a linearly tapered pole supported by a base rotational spring as shown in Figure 2. The external effects on the pole's vibrational response, caused by attachments such as cross arms and transformers, are included in the model as point masses and inertias. The two unknown model parameters, the pole taper and base rotational spring magnitude, are determined by matching the model's frequencies to measured frequencies through an iterative procedure.

In practice, testing a pole in the field involves attaching a sensor about 2 metres above the ground. The sensor is equipped with a spike that can be easily driven into the wood. The pole is tapped with a rubber mallet opposite the sensor, and the vibration response of the sensor is fed into the recording instrument. The operator must also enter the pole base diameter, height and attachment configuration data into the instrument. With a field instrument to process the data, the relative stiffness and strength would be available almost immediately.

USING VIBRANTE AS AN ACCEPTANCE TEST

Once the base spring magnitude and the amount of linear taper are determined, the pole sitffness can be easily calculated. While this calculated stiffness could be used as an acceptance test, a more meaningful acceptance test is to examine the relative stiffness of the base rotational spring. As previously described, a weak base spring corresponds to a decayed pole. The stiffness determined using the calculated base spring and linear taper can be compared to the stiffness of the same model with a very stiff base spring to determine a parameter called relative stiffness. Specifically, relative stiffness is defined as the ratio of measured stiffness (using the calculated base spring) to new undecayed pole stiffness (using an infinitely stuff base spring).

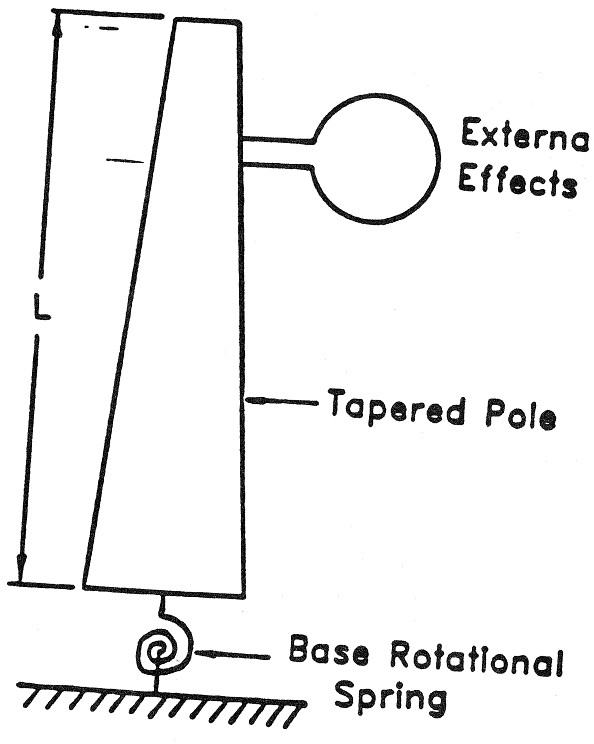

Figure 2: General Mode

Through a large testing program (described in the next section), proper relative stiffness acceptance levels are being established. Based on tests to date, it appears that levels of 0-75% (unacceptable), 75-90% (suspect) and 90-100% (acceptable) are appropriate.

Using these categories, a Vibrante testing program should include some conventional inspection to supplement the Vibrante results. When a Vibrante test result falls into the suspect range, a detailed conventional inspection should be conducted. In many cases, an explanation for a low Vibrante reading will be readily obvious. For example, a pole with a shaved ground line region (manually shaved prior to bandage treatment) could have a Vibrante reading in the suspect range. In other cases, where there was no obvious defect, a detailed core drilling program would be recommended to help establish the degree and type of defect.

It should be noted that, based on our experience, most poles from any testing program will fall into the acceptable category and would not require additional inspections. Similarly, some poles would fall into the unacceptable range and would not require further inspections. Thus, a Vibrante testing program could be considered a screening tool to significantly accelerate and improve conventional inspections.

TEST RESULTS

The accuracy of Vibrante is being tested and confirmed through three separate testing programs.

The first testing program, now complete, included comparing Vibrante stiffness predictions with static stiffness measurements. For this program, 196 poles from across Western Canada were tested with Vibrante. Static pole stiffness was obtained by attaching a cable to the top of the pole and measuring load and defection. This stiffness was compared with the stiffness predicted by Vibrante as shown on Figure 3.

FIGURE 3

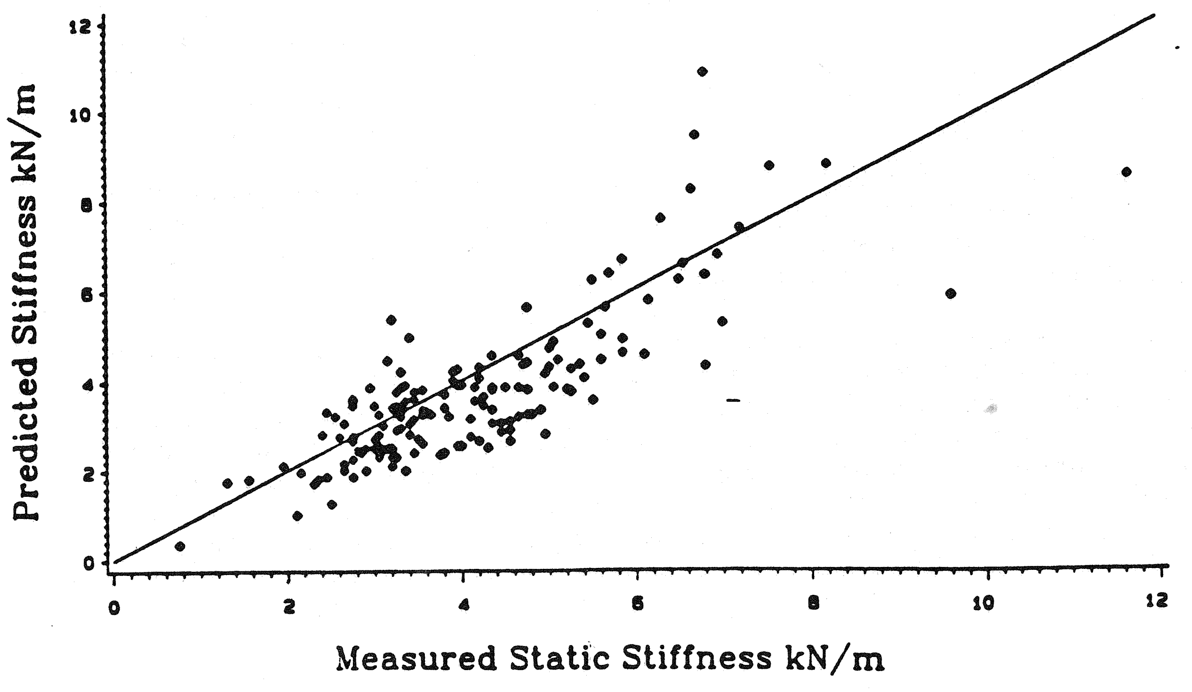

Figure 3: Test Results - Vibrante versus Static Pole Test

Figure 3 shows a linear relationship between the predicted and measured pole stiffness. The correlation coefficient for this data is 0.82 which, for a wood product, is considered a good correlation.

The second testing program consisted of taking in-situ Vibrante readings on old B.C. Hydro poles, then checking a representative sample through a detailed inspection involving soil excavation and several core samples. To date, over 400 poles have been tested by Vibrante with more tests planned for the near future. This testing has resulted in refinements to the acceptance levels, and has reduced B.C. Hydro's premature pole replacements. Over one hundred rejected poles near Smithers, B.C., for example, were shown to be acceptable by Vibrante and therefore saved for further service.

The final testing program, recently initiated, is a cooperative venture with Ontario Hydro. For this program, Ontario Hydro plans to destructively test up to two thousand poles in their lab and compare their statically measured stiffness and strength to that predicted by Vibrante. The main benefit of this program is in establishing the accuracy of Vibrante's strength reading. Establishment of this strength-stiffness correlation will be very useful to line designers, for example, in upgrading existing wood pole lines.

PRESENT RESEARCH

Based on the demonstrated success of Vibrante, the Canadian Electrical Association have continued to support the development work at B.C. Hydro. This work, scheduled for completion in late 1988, includes establishing the dynamic effects of conductors and other associated hardware, writing a finite element structural dynamics computer program, and continuing field testing to confirm the general applicability of the technique and to establish acceptance levels through experience.

The conductor and hardware effects are being studies by testing three full size test lines. One consists of six single poles to simulate a distribution line. The second, a transmission H-frame line, consists of a single H-frame structure and six single dead-end poles. The third test line includes two poles and several ground anchors to study guy effects. Results to date show that conductors and communication cables have a negligible effect on the Vibrante reading. On the other hand, rigid attachments, such as cross arms, have a significant effect on a pole's vibration behaviour and must be reasonably estimated and included in the analysis.

COMMERCIALIZATION

B.C. Hydro is presently transferring technology to a local company, Vibrante Technologies Incorporated (VTI), to build a portable testing instrument. VTI is currently designing the instrument and will be responsible for its manufacturing and marketing.

The portable instrument will be capable of performing on-site immediate analysis of a wood pole using the Vibrante method. Prototypes should be available in about one year and will be distributed to select utilities for six month trial periods.

CONCLUSIONS

The speed and accuracy of in-situ pole inspections should be improved in the near future by using a new non-destructive testing technique called Vibrante. The accuracy of the methods has been demonstrated on nearly 200 pole tests which were comparatively tested with static stiffness (load deflection) measurements. Further field trials are continuing and have thus far included over 400 poles. A final testing program, recently initiated with Ontario Hydro, will establish the correlation between measured pole breaking strength and Vibrante predictions.

The method is currently being developed into a small, portable field instrument capable of assessing the condition of a pole in under one minute. The instrument, being developed by Vibrante Technologies Incorporated, will be available for field trials in about one year.

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