NON DESTRUCTIVE TESTING OF TIMBER BRIDGE GIRDERS

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Abstract

It is recommended that timber bridges are inspected at a minimum of two year intervals to determine and rate the condition of the structure to enable the scheduling of maintenance and determine the effectiveness of past maintenance treatments. During these inspections it is necessary that a visual inspection be undertaken in conjunction with a drilling survey of all major structural elements.

Unfortunately current methods of drilling can promote the deterioration of these structural elements and the reserves of timber that are suitable for bridge construction and maintenance are scarce. It is therefore imperative that asset managers consider using alternative methods such as Non-Destructive Evaluation (NDE) during routine inspections.

The Resistograph is a quasi non-destructive evaluation tool that was developed for testing the soundness of European softwoods that is now available in Australia. This paper will present the results of testing the resistograph on timber hardwood bridge.

Keywords: Timber, bridge, non destructive testing, drill, resistograph

1 Introduction

The magnitude of use of timber bridges has been highlighted from studies undertaken by Yttrup and Law [1], Champion et al[2] and Yttrup and Nolan[3]. Today it is estimated that there are over 20,000 timber road bridges still in operation in Australia. Unfortunately timber is highly susceptible to deterioration mechanisms that may be either biological or mechanical and this is compounded with the increasing difficulties in obtaining suitable large sawn timber to replace deteriorated members. It is therefore necessary to determine the extent of deterioration of timber structures by Non Destructive Evaluation (NDE), so that appropriate remedial measures could be taken.

Deterioration of timber structures by biological means is one of the main grounds for maintenance; however the tools that help to detect the deterioration can also compound the problem. The semi-destructive techniques that are used, such as coring, probing or drilling, can aid in determining the extent of rot yet these mechanisms themselves can create a weakness in the material allowing rot to set it [4].

Drilling using a 12mm drill bit is currently the most common method used in timber bridge investigations. This form of drilling relies on the experience of the operator to “feel” the difference in resistance met by the drill to determine the extent of sound and decayed wood

Figure 1: Damage from testing

Figure 1 shows the external damage that occurs to timbers from numerous tests and even though the amount of damage that is caused by a 12mm hole may be considered negligible, the damage caused by continuous testing must be considered. Preventative treatments are required after drilling to reduce rot, but from examining structures it has been evident that this procedure is not always carried out. Other forms of non-destructive testing must be considered when this failure in quality assurance and the repetitive and numerous locations that drilling is undertaken, is considered.

2 Background on the Resistograph

The Resistograph is a quasi non-destructive testing method originally developed for the testing of softwoods in Europe. The Resistograph is based on the resistance of a small diameter drill bit (1.4mm diameter). The drill is advanced at a constant speed through the timber thereby correlating the density of the material. Even though the bit is still permanently destroying some of the timber the hole is back-sealed and therefore limits the ingress of decay while also having a negligible effect on the overall structural system.

The data that is obtained from this method can be stored in a computer or printed out as the drill penetrates into the material. As the printout correlates to the distance drilled, the operator can easily judge where deterioration has occurred due to the decrease in density of the material.

An example of a processed drilling is shown in Figure 2. The y-axis indicates the relative magnitude of the torque required by the drill to keep the bit moving at a constant speed. The x-axis indicates the depth that the drill has penetrated into the timber. After processing, information such as the location of cavities or advanced decay is indicated by cross-hatching. Further information such as the timber being soft or suspect can be included in the assessment if required.

The line shown on the photo of the girder in Figure 2 shows the approximate drill path. From examining the processed data it can be seen that the resistance of the timber dramatically drops at approximately 7.5cm and continues with negligible resistance for the rest of the drilling. However there is a discrepancy at around the 2cm mark. It is believed that the drill bit travelled along a crack in this softer area of the exterior fibres. This result correlates almost perfectly with the location of the void. It should be noted that the drill did not re-enter the solid timber. If this occurred the graph would have rapidly increased thereby showing a “U” shaped curve.

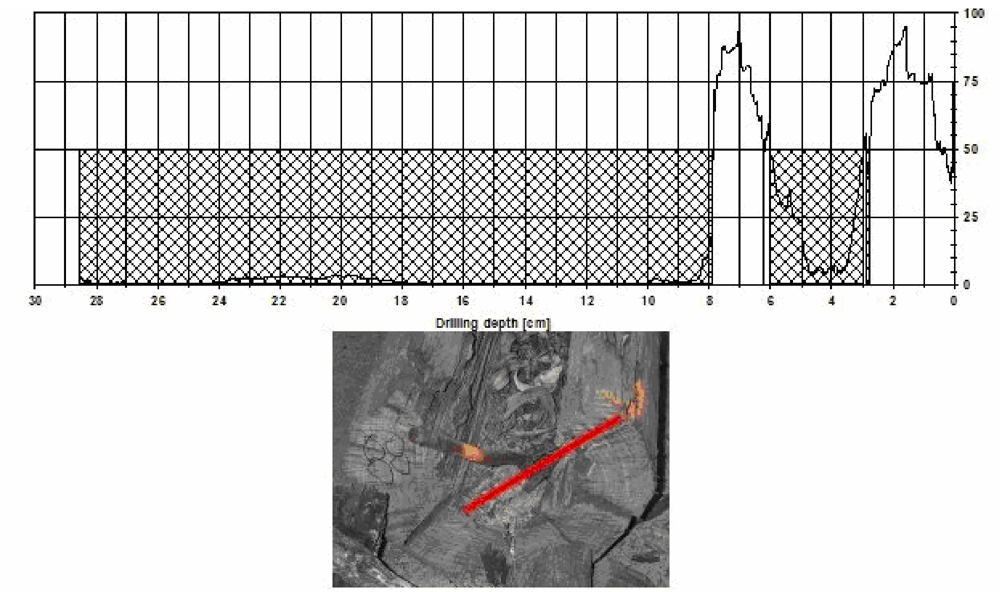


Figure 2: Resistograph Analysis

3 Testing Program

Non-destructive drilling, using the Resistograph, of 12 girders that were to be used in future destructive testing was undertaken before destructive testing. During the one and a half days of testing 92 points were tested.

The following steps were undertaken for the testing:

1. Before drilling commenced, each girder was marked with a specimen number and drill locations at approximately 1m centres.

2. Measurements were undertaken in three locations to determine an average diameter of the girder.

3. Each drill hole was given a unique code. This code reflected the girder number and the drill location. The left end of the girder was determined to be position 1.

4. The Resistograph was aligned with the girder so that the probe would pass through the centre of the girder.

5. At the end of each drill, the unique code was written on the paper printouts. Any comments regarding possible problems with the reading were recorded on the printout.

6. At the end of each day, the electronic file was downloaded to a computer for storage of the data.

7. Initial analysis of the drilling data was undertaken by an arbourist from Tree Testing Australia that was trained in the use of the resistograph.

8. Destructive 4-point bending tests were undertaken as part of a capacity determination project[5].

9. The girders were cut at the drill point locations following the destructive testing and a photographic record of each cut was taken. Note: In some instances this was not practical due to the location of bolts in the girders.

10. Verification between the analysed data and the actual samples were undertaken to determine if the resistograph had actually determine the degree of rot and piping at the drill locations.

4 Results

4.1 On Site Usage

Average drilling times using rechargeable batteries equated to approximately 5 minutes per hole. This time allows for changing of batteries, paper indicators, computer identification codes and drill bits. During general use, the rechargeable battery requires changing every six to seven drills when drilling into sound timber. If this process is not followed the risk of breaking a drill bit increases as the bit can not take the increased friction that is induced when it is forced to start spinning once imbedded into the timber.

The testing undertaken during the project was the first on Queensland's timber bridges. The tool was initially developed in Germany for testing live softwood trees. As such the difficulties encountered during the testing are not unreasonable. Further testing and modification of the tool should reduce most of the problems experienced.

4.2 Analysis

Initial analysis of the results of the drilling data undertaken by the abourist indicated that only 29% of the tests correlated with the actual samples of the cut girders. An example of a girder with correct predicted results is shown in Figure 3.

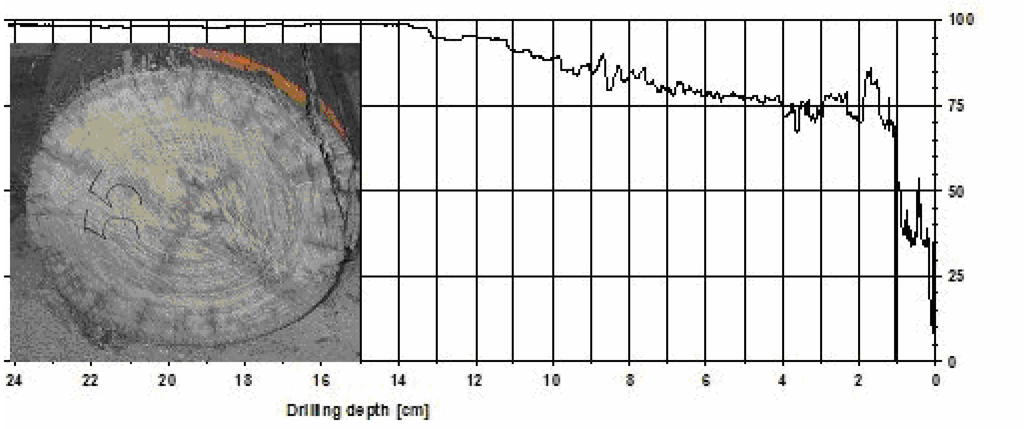


Figure 3: Correct Analysis

Further investigation of the results showed that are large percentage of the "failed" tests indicated that there were cavities located in the first 5 to 8cm of the surface of the girders. An example of cavities being detected in the first 5 to 8cm of the girder is shown in Figure 4. The line on the picture of the girder indicates the approximate drilling path. From examination of the photo, it can be seen that there are no voids in the first 1-9cm of the girder as was indicated by the hatching on the printout. However, from further examination of the cross-section cracking can be seen extending towards the heart of the girder. It is concluded that due to the timber being softer in the location around the cracks that the resistance is lower in the outer region of the girder and that the drill bit had a tendency to follow these cracks. It is for this reason that while considering the predicted results that this outer section of the girder has been discarded during consideration of the results of the overall effectiveness of the resistograph.

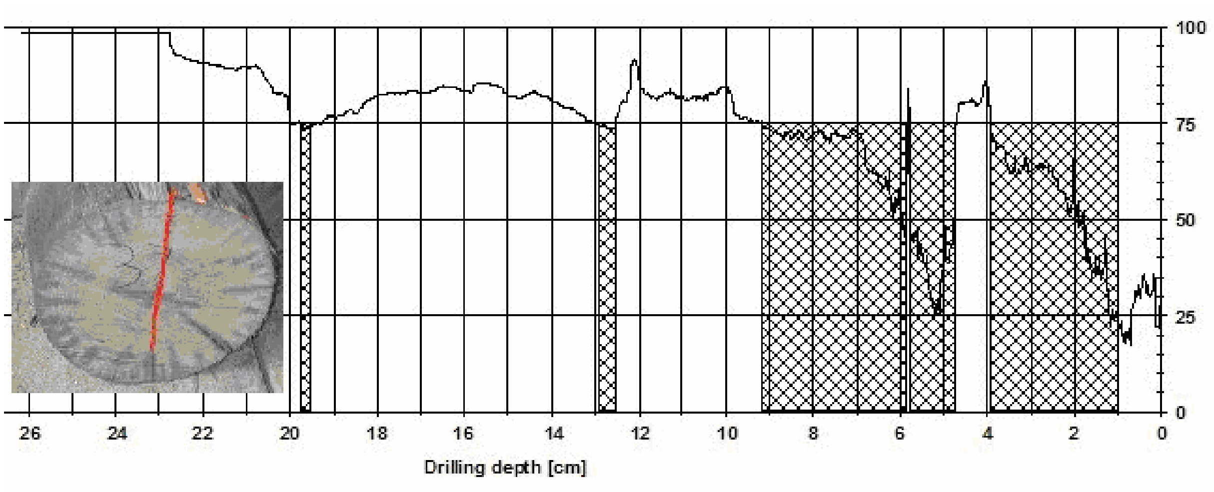


Figure 4: Cracking Identified as Cavities

Of great concern is the Resistograph not detecting piping and rot in the centre of the girder. Two examples of this situation can be seen in Figures 5 and 6. The red line in Figure 5 indicates the path that the drill must have taken. From examining the drill path, it can be seen that it passes between two sections of rot. This problem is also experienced with conventional drilling. As the exact location of a defect is not known it is possible to not detect a defect.

The large orange dot in Figure 6 indicates the starting position of the drill. It can therefore be seen that a large deviation in the direction of the drill bit was necessary to avoid detecting the large centrally located void.

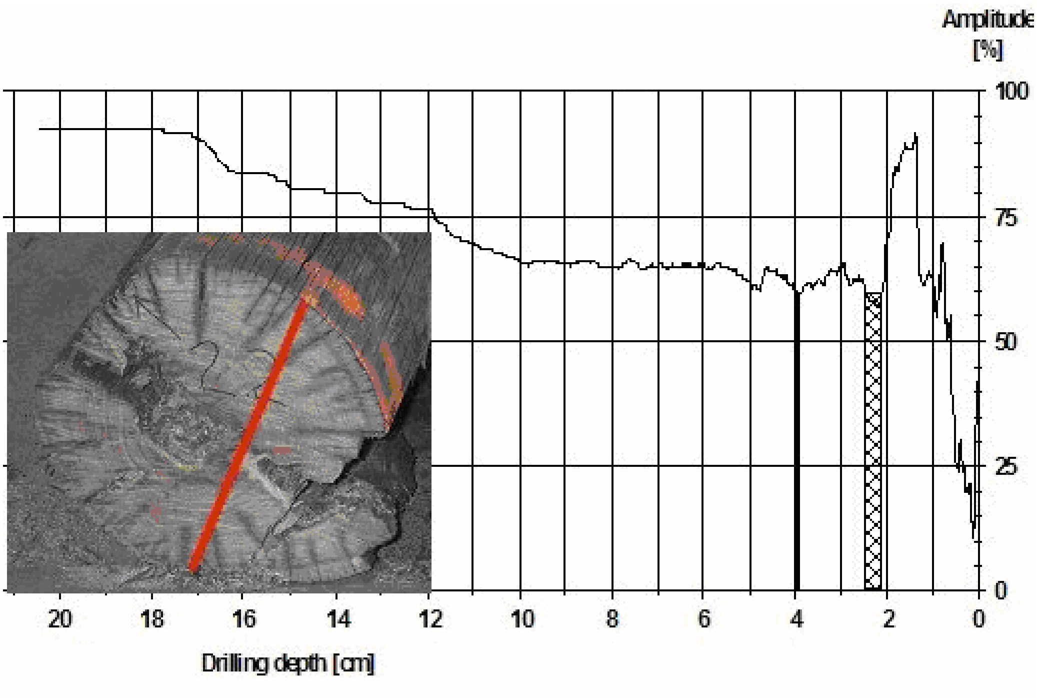


Figure 5: Missed void and rot

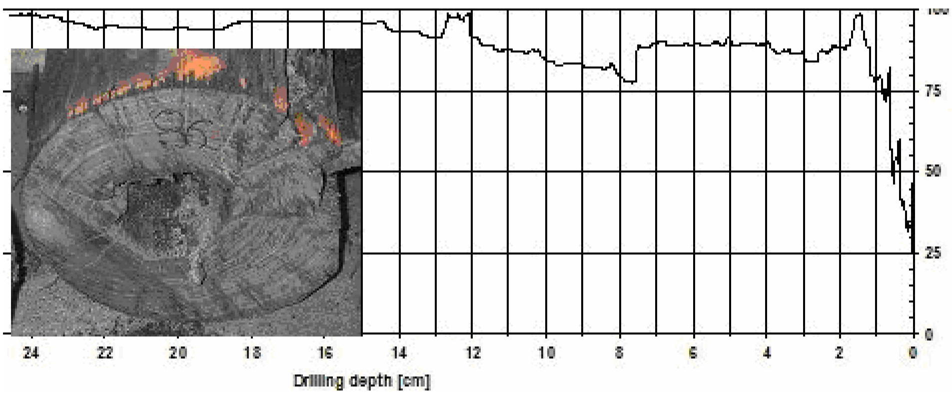
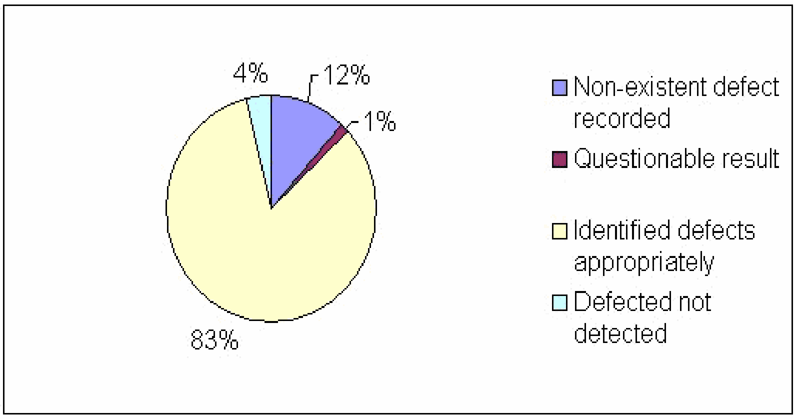


Figure 6: Missed large void



As previously discussed the resistograph has a tendency to show false cavities in the first 5 to 8cm of the girder. When this portion of the girder is omitted from the analysis, the Resistograph is able to identify rot and voids in timber girders with an accuracy of approximately 83%. A breakdown of the result categories can be seen in Figure 7 when this method of determination is taken into consideration.

Figure 7: Percentage of Results in Each Category

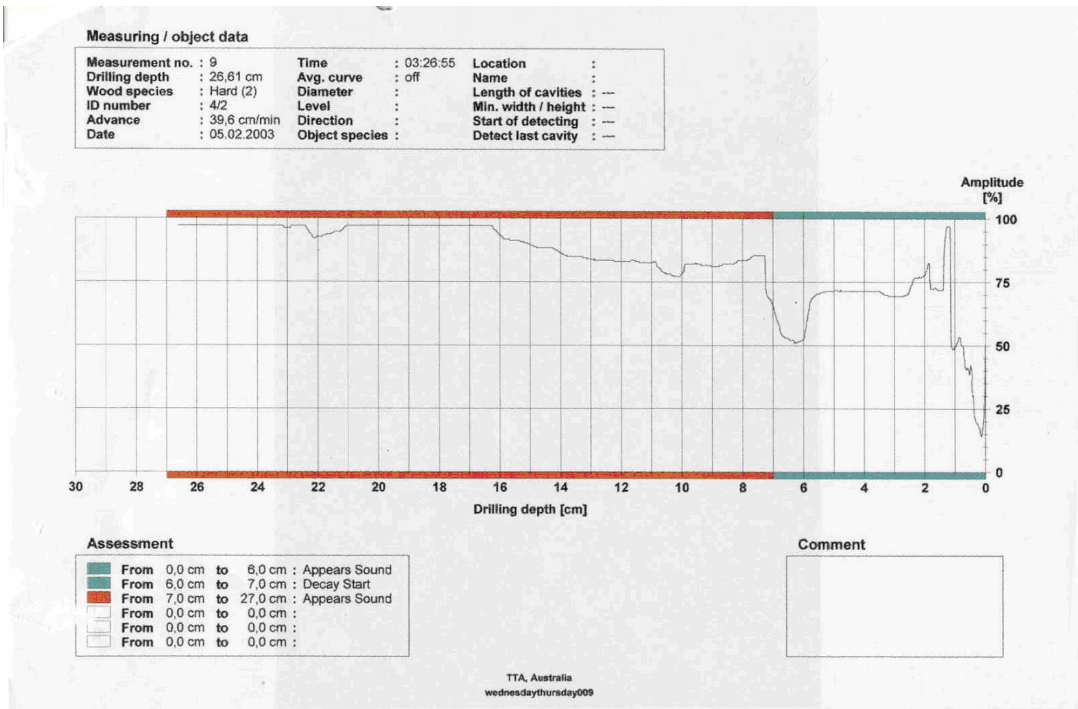


Figure 8: Results after Processing

4.3 Format of Analysis

A typical processed drill report is shown in Figure 8. In general, the results are presented clearly with both a visual and numerical interpretation of the degree of piping in the member. As part of the analysis the "Assessment" box was not always utilised. The use of this colour coding system would be a benefit to the end user to allow for a more detailed understanding of the state of the member. However, care must be taken to ensure that different colours are used to signify the different degrees of decay in the member.

5 Recommendations

As the tests were performed as a stand-alone test, it is believed that if the drilling is undertaken in conjunction with out NDE such as a Nuclear Densimeter that an accurate condition description could be obtained for timber bridge components. By undertaking both forms of non-destructive testing techniques the number of sound timber components that are drilled and the number of components removed in error will be minimised.

Further enhancements are required to the testing processes to ensure that large defects such as those previously mentioned are detected. To enable this to occur the following items, need to be considered before the Resistograph can be used effectively in the field:

- Stability during drilling;
- Crack identification;
- Drilling location; and
- Reporting.

5.1 Crack Identification Recommendations

Previously it was discussed that a number of the results showed that there were cavities located in the first 5 – 8 cm of the girder. Due to the number of false readings that were found in this region a methodology to limit the percentage of false interpretation is required.

As the cracks that penetrate into the girder are usually visible on the surface of the girder the following steps should be followed:

- Ensure that the drill is not positioned directly on a crack.
- If possible try to locate the drill at least 2cm away from a crack.
- The results of a visual inspection of the girder at the drill location should be recorded.
- Ignore surface defects that have been recorded if the girder is visually sound.

It should be noted that typical bridge girders range in size from 45 to 50cm in diameter so this methodology does not negate a high percentage of the drilled length.

5.2 Drilling Location Recommendations

Based on the testing undertaken and previous testing undertaken using Nuclear Densimeter the following locations should be drilled during inspections:

- Vertically and/or horizontally along the centreline of the girder. If a defect is located drill from the opposite side of the girder and orthogonally to the original location to locate the void or defect; and
- 50 – 100mm above the horizontal centreline of the girder.

It has been noted through other forms of NDE that rot often starts in the area under the spiking plank. By undertaking drilling in both of the locations indicated, rot in this area can be identified. This will thereby allow the inspector to assign a more accurate condition rating to the girder.

5.3 Reporting Recommendation

For an immediate view into the degree of deterioration of the member in the field, the printout provides a good indication. However, training would be required by the field operators as to what percentage of maximum amplitude is significant to indicate rot or piping.

Post processing of the data requires further attention to detail. As was discussed the first 5 - 8 cm of the girder has been ignored during the analysis of the results. It is proposed that this section of the graph be marked to indicated the variability of the girder. In addition, care must be taken to ensure that the colours used in the legend differ for each condition state of the timber.

Investigations into the viability of engaging an arbourist to perform drilling, leasing or purchasing the Resistograph must also be considered. The approximate time involved in fully analysing the data obtained from drilling is approximately equal to the amount of time spent drilling (i.e. One day in the field equates to one day analysing the data). If an arbourist is engaged to perform the drilling, the cost of analysis must be considered. However, if the Resistograph is leased or purchased the cost of purchasing and maintaining the software, man-hours for performing the analysis and the initial purchase price/on going lease price of the equipment must be considered.

6 Conclusion

With an accuracy of approximately 83%, when the first 5 to 8cm of drilling is omitted, the Resistograph is a powerful tool that minimises the amount of damage inflicted on a timber element when used as a stand alone tool. When compared to the standard drilling method currently used the Resistograph has the following advantages:

- It is less destructive on the girder;
- It does not rely on the operators experience; and
- The printout gives a clear indication of the size and location of pipes instantly.

In summary this technique has proved to be feasible and efficient for use in structural condition monitoring and damage identification in timber bridges.

7 References

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