Measuring Soil Stresses and Deformations during Sugar Cane Harvesting

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Introduction

In recent years there has been an increase in research activity into the compaction consequences of cane growing, focusing on the major traffic occurrences during harvesting operations. Nominal row spacing for growing sugar cane is 1.5m, whereas most harvesting equipment has a wheeltrack of approx 1.85m. Due to this anomaly, under normal circumstances, wheeltracks on harvesting equipment pass close to, if not on top of, the cane stool. Combined with the fact that each row receives a minimum of two passes of a harvester and two of a haulout it would seem that this application of controlled traffic has the potential for some significant compaction consequences.

Sugar cane is grown in rows over several years. With a statewide average of 3.9 ratoons, sugar cane is somewhat different to other controlled traffic crops in that the beds and wheeltracks are in some cases permanent for 5 years. With the increase in green cane trash blanketing, which utilises minimum or zero tillage, and given the high number of passes each row receives during harvesting it is evident that this application of controlled traffic farming has a special set of circumstances.

The work described in this paper was undertaken as part of a wider project setup by the BSES and the USQ to investigate the linkages between machine traffic, soil conditions and productivity in the sugar industry. Two key USQ objectives in meeting the projects aims were to :-

- quantify the stresses that occur within a soil under a range of cane machinery
- establish the extent to which the soil stresses spread from the machinery path under the crop rows with a range of soil types and conditions.

To carry out these objectives I have set out to obtain field measurements of stress and deformations that occur within the soil under a range of traffic and soil conditions.

Methodology

The stress measurements were made at 2 depths (approx 150 and 250 mm) in two trial plots at Tully and one at Ingham. During the '94 harvest the first plot at Tully was at 2nd ratoon stage while the second plot was being harvested for the first time. The plot at Ingham was 1st ratoon. The same plots were used again during the '95 harvest. Harvesting equipment at Tully consisted of an Austoft harvester and high flotation haulouts , while the equipment used at Ingham included a full track harvester and a combination of conventional and high flotation haulout bins. Soil deformation measurements were made in the same locations as the stress measurements.

The soil type at Tully is a yellow silty clay while there is a self mulching black clay soil at the Ingham site.

Other data obtained include tyre sizes and inflation pressures as well as soil moisture and density.

A Soil Stress Transducer (SST) has been developed and used by researchers from the USQ over several of years under several different conditions, mainly in the cotton industry. This SST is based on a set of six miniature pressure sensors mounted on an approximate sphere of 40 mm dia. (Harris & Bakker 1994). When combined with a high speed data acquisition unit and laptop computer, the SST allows pressures transmitted through the soil body by surface loadings to be recorded. The six pressure sensors are aligned in different directions so that the total state of stress at a point can be mathematically computed.

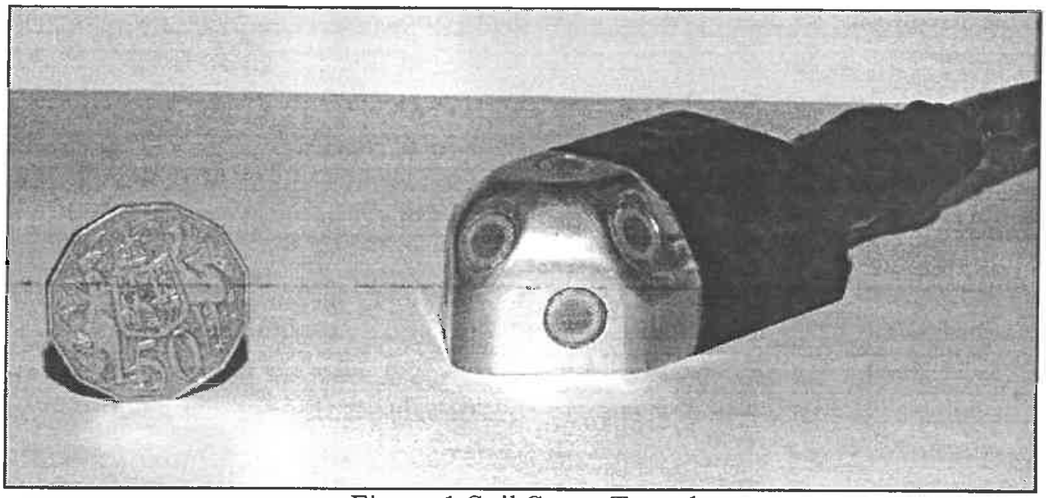

Figure 1 Soil Stress Transducer

During the harvest, the measurements are made as follows:-

(i) The SST is installed by digging a trench at right angles to the row. A core is taken from the end of the trench to leave a tunnel under the row. This is then reamed out apart from the end 10cm.

(ii) The SST is placed inside a soil plug in an open ended perspex cylinder. This plug of soil, containing the SST, is then inserted into the tunnel and pushed into the unreamed end section thereby ensuring good contact. The perspex cylinder is then withdrawn and the trench backfilled.

(iii) The data acquisition system and operator initially record the first pass of the harvester from two rows away, in uncut cane. On the return pass the harvester is only one row away as the SST is passed over for the second time. The equipment is then relocated to the cut cane side of the harvester as the haulout impact is recorded as it passes over the SST.

(iv) After the data has been downloaded, the SST is excavated for relocation to a new pit and the process repeated at a different installation depth.

The method adopted to measure soil deformation from cane traffic is the point grid method developed by Derk Bakker. It involves excavating a narrow pit across the row. The dimensions of the pit are 1.2m in length, 0.5m deep and 0.2m wide. The pit is kept as narrow as possible to minimise any influence on the actual stresses. A perspex board with holes drilled on a 50mm grid is used to insert displacement pins two longest sides. Wooden pegs are placed in the corners of the pit as a reference and to allow the board to be levelled. After installation of the matches the board is taken away and a plastic sheet stretched over a metal frame is located in its place. The position of the match heads are then mapped onto this sheet using permanent marker pens. The original ground surface is also marked onto the plastic. The pit is then carefully backfilled, trying to get the soil close to its original density.

After harvesting the pit is re excavated, the plastic sheet put back into place and the new position of the pins recorded.

Two pits were used in both the of plots. One was for a single pass and the other pit for multiple passes. Bulk density samples were taken across the pit at several different depths before and after trafficking to quantify the bulk density changes that might have occurred.

Horizontal and vertical displacements for each match are determined by placing the plastic sheet over the perspex board used to insert the matched and the before and after positions measured relative to each grid point.

Results

The results from the SST are converted to pressures through laboratory calibration. This involved placing the SST inside a plug of soil which was then placed inside a steel chamber. Air pressure was then applied and the sensors read for a number of different pressure levels.

The results are initially displayed in terms of the pressure recorded by each sensor. They can then be used to calculate the stress path in terms of the octahedral shear stress q and the normal stress p. This provides information on the relationship between the applied loading and the soil response.

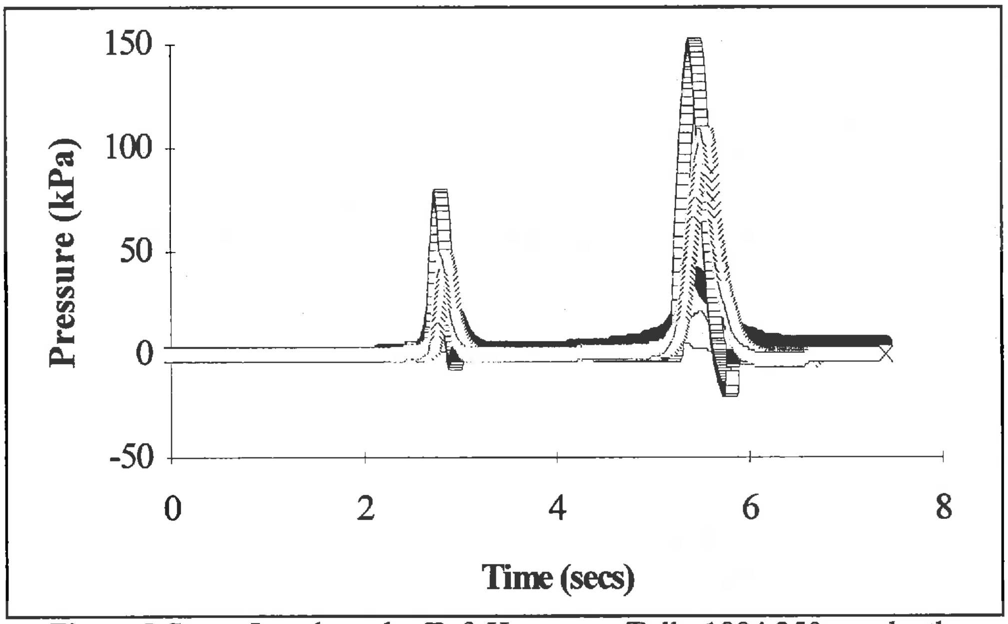

Figure 2 Stress Levels under Toft Harvester. Tully 1994 250mm depth.

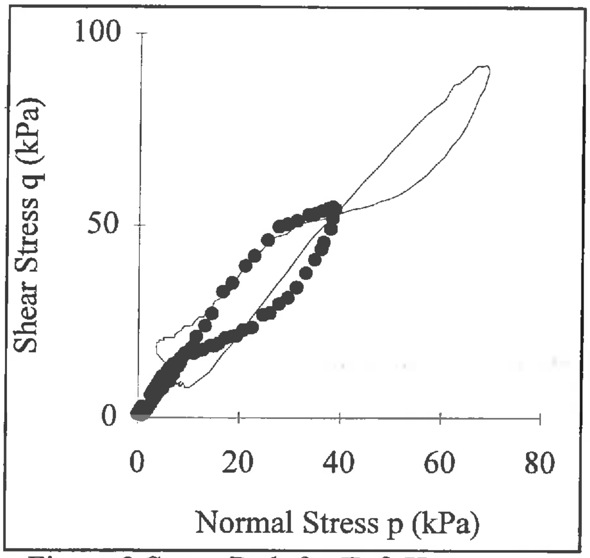

Figure 3 Stress Path for Toft Harvester
(•) Front tyre (——) Back tyre

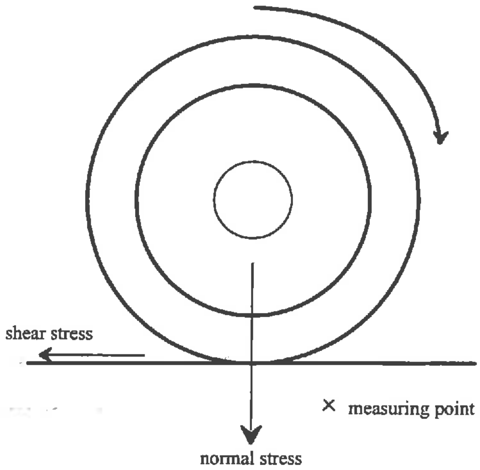

Figure 4 Schematic of process

The pin displacement results can be plotted to show the relative movement of each point on the pit face. Clearly the largest movement is expected to be directly under the tyre centre line close to the soil surface but the displacements at depth and also the sideways provide us with useful information. The point displacements can also be converted to bulk density changes by analysing the change in area of each square region of the grid. This can be compared to those changes found using the bulk density samples.

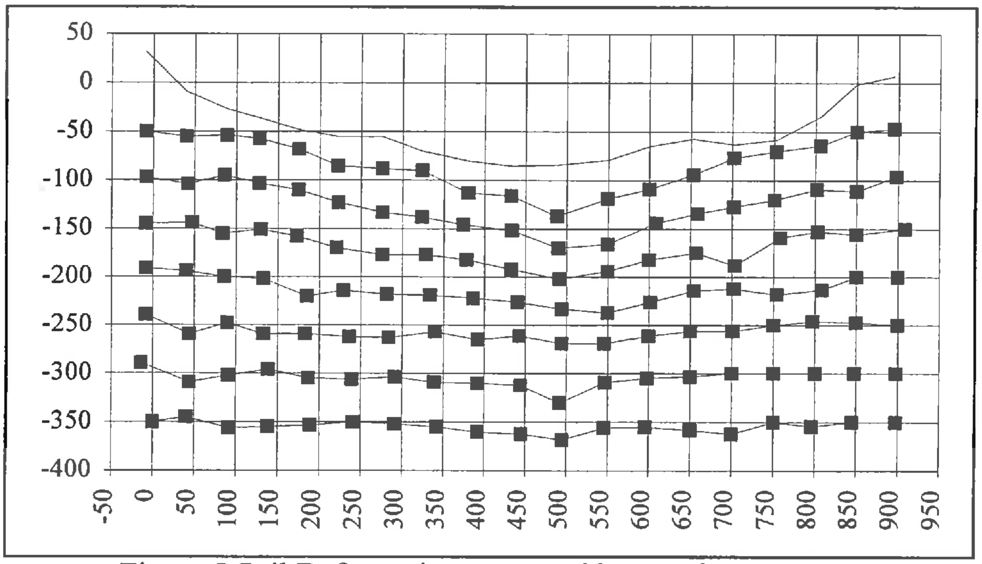

Figure 5 Soil Deformation measured by match movement
Caused by Single Pass of Toft Harvester, Plant Crop

Discussion

The SST has provided some much needed data on the levels of stress transmitted by cane harvesting equipment. The equipment is reasonably robust and reliable considering the unfriendly environment. Some initial problems were encountered with installation of the SST but these were overcome as experience was gained with the procedure. The soil deformation measurements , while involving a considerable amount of time and effort have provided some valuable data, as illustrated in Fig 6.

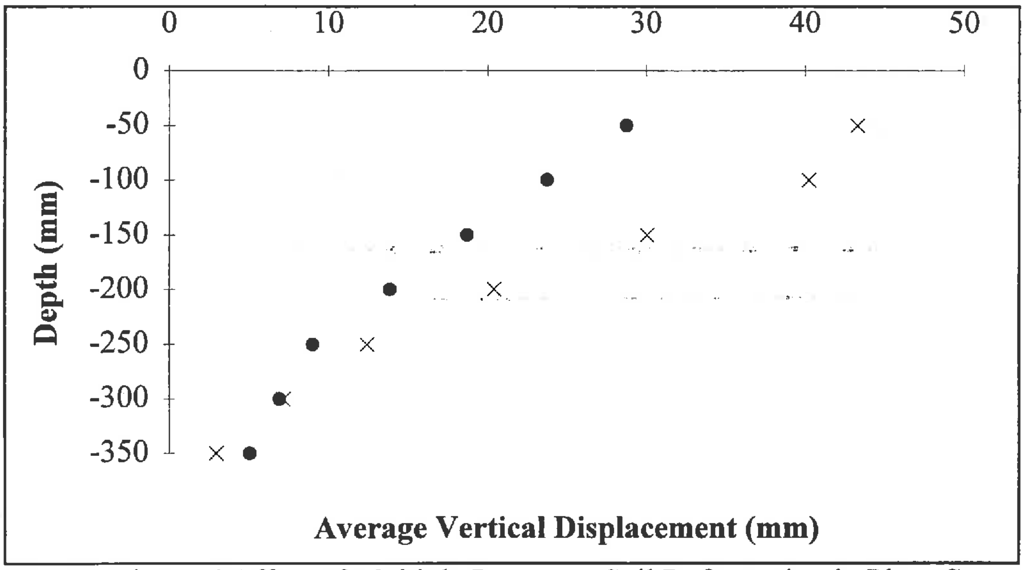

Figure 6 Affect of Multiple Passes on Soil Deformation in Plant Crop
(•) Single Pass (1 x Harvester) (×) Multiple Passes (2 x Harvester, 4 x Haulout)

At present this data is being used in the calibration and verification of a computer model that can be used to simulate a number of traffic inputs and determine their effects upon the soil. If this model is successful it will then be able to be applied to a range of soil type harvesting conditions etc.

By combining these data with the yield and other relevant data the BSES are collecting from the trial plots, a practical insight into the compaction consequences of controlled traffic in the sugar cane industry will be gained.

References

Harris H.D and Bakker,D.M 1994 A soil stress transducer for measuring in situ soil stresses. Soil & Tillage Research 29:35-48.