# CHARACTERIZATION OF LTPP PAVEMENTS USING FALLING WEIGHT DEFLECTOMETER

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**ABSTRACT**
In this paper, the characteristics of the falling weight deflectometer (FWD) deflection were studied using a simplified deflection model in the form of Y = K1 exp (-X/K2) + Y0. The exponential curve was found to have the desired characteristics which match the FWD deflection bowls. In the equation, Y is the FWD deflection in microns and X is the radial distance in millimetres. The coefficients K1 and K2 of the model describe the structural characteristics of the pavements. The deflection model has been adopted in assessing the structural characteristics of road pavements in several City and Shire Councils in Southeast Queensland (SEQ). FWD deflection data used in the study are obtained from the 65 long term pavement performance (SEQ-LTPP) sites located within the region. The results indicate that the coefficient K1 and K2 are unique for each of the LTPP section selected in the study. The study suggests that the coefficient K1 is closely related to FWD deflection D0 and K2 is dictated by the strength of the pavement layers. The simplified deflection model developed in the study can be used to delineate the pavements with cement stabilised and natural gravel bases and pavements with poor subgrade.

***KEY WORDS***
*LTPP, Pavement, FWD, deflection model*

## INTRODUCTION

Deflection basin parameters from FWD testing device are used extensively for assessing the structural integrity of a pavement and to back calculate the in situ layer moduli of a pavement. Pavement structural deformation is greatly dependent on the performance of the various pavement layers and the quality of the pavement subgrade. FWD is also used by highway agencies for network level deflection survey for assessing the rate of pavement deterioration and to determine the timing for rehabilitation.

In this paper, the characteristics of the falling weight deflectometer (FWD) deflection were studied using a simplified deflection model in the form of $Y = K1 \exp(-X/K2) + Y0$. The exponential curve was found to have the desired characteristics which match the FWD deflection bowls. In the equation, Y is the FWD deflection in microns and X is the radial distance in millimetres. The coefficients K1 and K2 of the model describe the structural characteristics of the pavements. The deflection model has been adopted in assessing the structural characteristics of road pavements in several City and Shire Councils in Southeast Queensland (SEQ). FWD deflection data used in the study are obtained from the 65 long term pavement performance in Southeast Queensland (SEQ-LTPP) sites located within the region.

The six Local Government Authorities maintain a total of about 7,558.2 km of paved roads. The paved roads are either Spray Seal or Asphaltic Concrete. Generally, the surfacing can have a thickness ranging from 10mm to 50mm.

## FWD TESTING PROGRAM

The approach used to select the LTPP sites is to group sections of road of similar construction, traffic loading and age of construction together within a matrix and thereafter making the assumption that all road sections lying within a particular matrix element will behave in a similar manner[1)]. 65 SEQ-LTPP sites representing the entire six participating LGAs road network were jointly identified by Griffith and the six LGAs.

Each site is reasonably homogeneous of 250m in length. Three recognised primary parameters were used in the selection of the calibration sites including: Construction types (Thick, Medium and Thin); Traffic loadings (Heavy, Medium and Low) and Pavement age (Old, Medium and Young). All LTPP sites were selected in areas where no major maintenance (reconstruction or periodic) was carried out since construction. The objective of this is to determine pavement deterioration patterns without the influence of pavement works. Wherever possible, the sites were also selected from pavement section with different type of constructions namely the foamed bitumen and cement stabilised road base, spray sealed and asphaltic concrete surfacing.

The FWD deflection measurements were taken at 25 meters interval along the outer wheel path of a road lane in the entire SEQ-LTPP site[2)]. The deflection tests were carried out at all the 65 LTPP sites and all the testing works were completed in 2006. The location of the FWD test points were accurately identified and located so future tests can be performed at the same locations. The load level used for the FWD drops was 50kN, which corresponds to a load pressure of approximately 750 kPa. Seismic geophones which monitor the deflections were placed at 0 mm, 200 mm, 300 mm, 450 mm, 600 mm, 900 mm, 1500 mm, 1800 mm and 2100 mm offsets to measure the full pavement deflection basin. Readings from 9 geophones and including the one located at the centre of the loading plate were reported.

During the deflection test, the temperature of the asphalt was measured at an appropriate time intervals. The deflection data were corrected to the average working temperature of the pavement for the particular location. The average working temperature of the pavement is referred to as the Weighted Mean Annual Pavement Temperatures (WMAPT). The WMAPT are grouped into 4 temperature zones in the state of Queensland[3]. The deflection data were multiplied by the adjustment factors to correct for the difference between the measured field temperatures and the WMAPT for the particular temperature zone. The respective adjustment factors were determined from Figure 10.2 in Austroads[4] on the Temperature Correction for Deflection and Curvatures.

## MODELING OF FWD DEFLECTION

It is possible to model the FWD deflection data obtained from the SEQ-LTPP sites using an exponential curve in a mathematical form of Y = K1 exp (-X/K2) + Y0. The exponential curve was found to have the desired characteristics which match the FWD deflection bowls and will be termed as a simplified deflection model. The simplified deflection model and it's parameters are explained as follows:

$$Y = K1 \exp(-X/K2) + Y0 \quad \textbf{(1)}$$

where

Y = FWD deflection in micron;
Y0 = a constant;
X = radial distance in millimetres from the load axis; and
K1, K2 = structural parameters

More than 600 FWD deflection data obtained from the 65 SEQ-LTPP sites have been modeled using the simplified deflection model. For an illustration, the deflection results of 12 LTPP sites comprising all types of pavement constructions will be presented in this paper (see **Table 1**). Pavement coring and Dynamic Cone Penetrometer were carried to determine the thickness of the surfacing layer and to assess the strength of the subgrade layer. The LTPP pavements consist of thin sprayed seal (10-25mm) and asphalt pavement (25-50mm) surfacings with either granular or cement stabilized road base layers vary from 150mm to 400mm. The LTPP sites also consist of pavements with subgrade CBR values of less than and greater than 5. The traffic volumes in the local roads are considered low to moderate with traffic count ranging from 250 AADT (with cumulative equivalent standard axle loading of less than 0.30 million standard axle/year) to 10,000 AADT (with cumulative equivalent standard axle loading of greater than 0.30 million standard axle/year). The standard axle loading consists of a dual-wheeled single axle, applying a load of 80kN[5].

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**Table 1**: 12 SEQ-LTPP Sites

| LTPP Site No. | Road Name | Surfacing Type | Surfacing Thickness (mm) | Road base Type | Subgrade CBR (%) |
|---|---|---|---|---|---|
| RSC05 | Panorama | Seal Coat | 55 | Cement Stabilized | > 5 |
| GCC04 | Xanadu Court | Asphalt | 24 | Cement Stabilized | > 5 |
| GCC13 | Larch Street | Asphalt | 25 | Cement Stabilized | > 5 |
| LCC01 | Chambers Flat | Asphalt | 63 | Granular Base | > 5 |
| LCC05 | Watland | Asphalt | 35 | Granular Base | > 5 |
| CCC05 | Queens | Asphalt | 35 | Granular Base | > 5 |
| LCC08 | Lawnton | Asphalt | 22 | Granular Base | > 5 |
| LCC11 | Sport Drive | Asphalt | 48 | Granular Base | > 5 |
| CCC10 | Burys | Seal Coat | 9 | Granular Base | > 5 |
| CSC08 | Avon Avenue | Asphalt | 35 | Granular Base | > 5 |
| GCC03 | Dudgeon Drive | Asphalt | 45 | Granular Base | < 5 |
| ICC03 | Commercial | Asphalt | 40 | Granular Base | > 5 |

## PRESENTATION OF RESULTS

The results of the FWD deflection basins and that generated by the simplified deflection model for the 12 SEQ-LTPP sites are presented in **Figure 1** to **Figure 12**. **Table 2** provides a summary of the structural parameters K1 and K2 for the deflection models at all the SEQ-LTPP sites. A graph has been prepared in **Figure 13** to demonstrate the effects of parameter K1 and K2 have on the deflection curve. The graph shows that as the parameter K1 increases, the FWD deflection D0 would also increase. Contrary to parameter K1, parameter K2 would give an opposite effect on the deflection D0 data. The parameter K2 would exhibit an increasing value as the deflection D0 decreases.

From **Table 2**, it can be observed that parameter K1 varies from 310.18 to 1484.95 and the parameter K2 varies from 318.96 to 733.80. The value of Y0 appears to be influenced by the deflection $D_{2100}$. When $D_{2100}$ recorded a high deflection value, the value of Y0 tends to be high. The parameters K1, K2, and Y0 are unique for each of the 12 LTPP pavement sections considered in the study. Pavement sections in RSC05, GCC04 and GCC13 LTPP sites are of cement stabilized base construction can be classified into a group with similar pavement characteristics since the parameters K1 and K2 for these LTPP sections are nearly identical. K2 would have a high value when the stiffness of the stabilized base layer increases as observed in GCC13 site.

Another observation can be made for pavements with granular base construction and with subgrade CBR greater than 5 such as LTPP Sites LCC1, LCC5, LCC8, LCC11, CCC10, CSC08 and ICC03 is that the values of K1 varies from 400 to 700 and K2 would vary from 300 to 500. For GCC03, the K1 value increases to 1,484.95 and a possible reason for the high deflection is that the subgrade CBR in this road section has an index of less than 5. The 11 SEQ-LTPP pavement sections can thus be grouped into three distinct classes on the basis of the structural parameter K1 and K2.

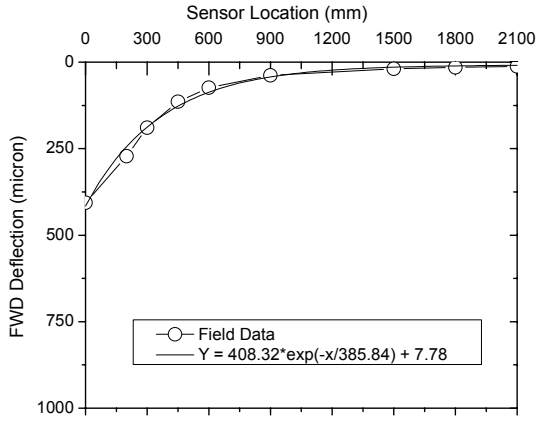


**Figure 1** Deflection at LTPP No: RSC05

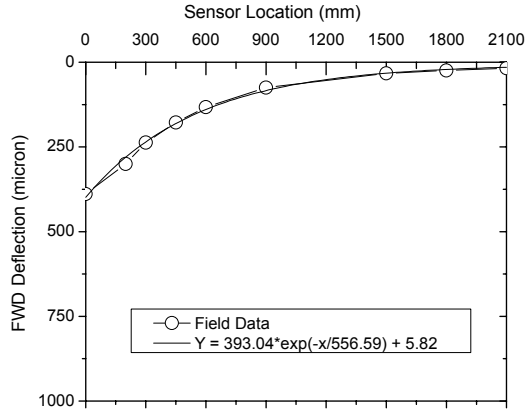


**Figure 2** Deflection at LTPP No: GCC04

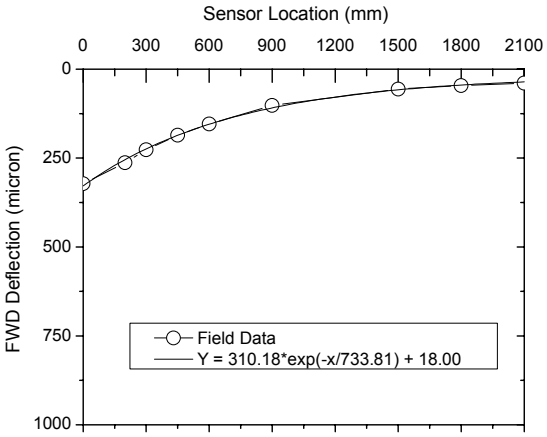


**Figure 3** Deflection at LTPP No: GCC13

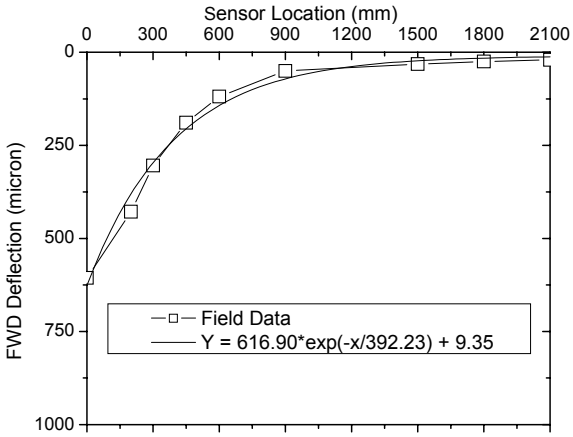


**Figure 4** Deflection at LTPP No:LCC01

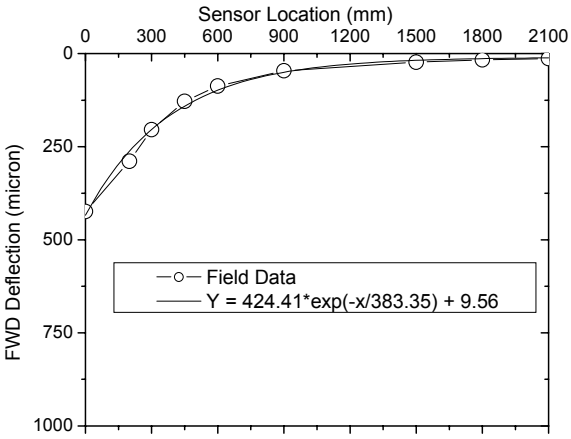


**Figure 5** Deflection at LTPP No: LCC05

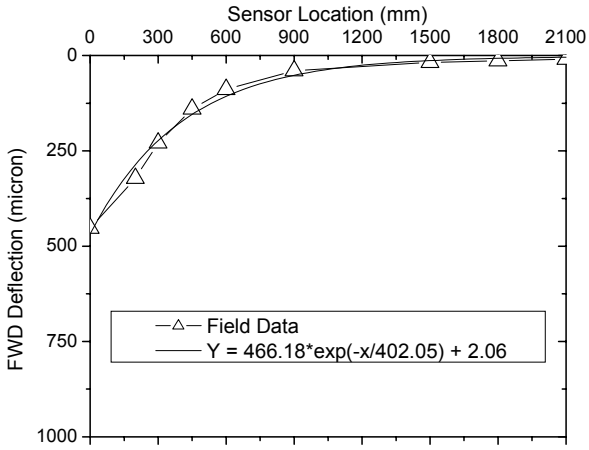


**Figure 6** Deflection at LTPP No: CCC05

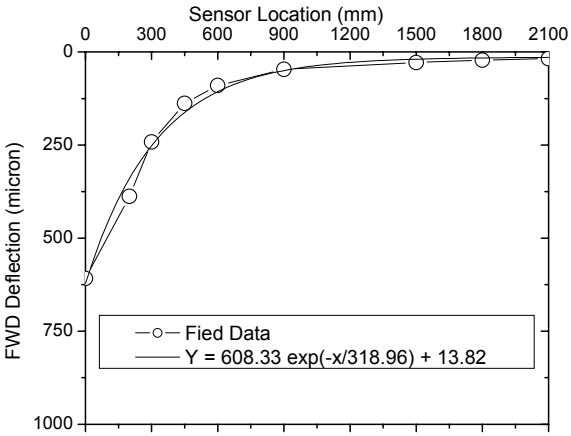


**Figure 7** Deflection at LTPP No: LCC08

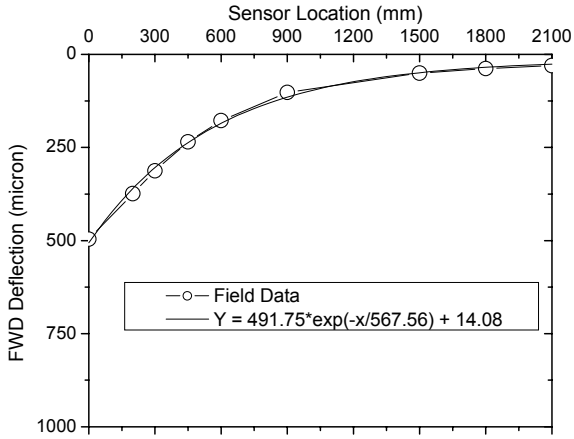


**Figure 8** Deflection at LTPP No: LCC11

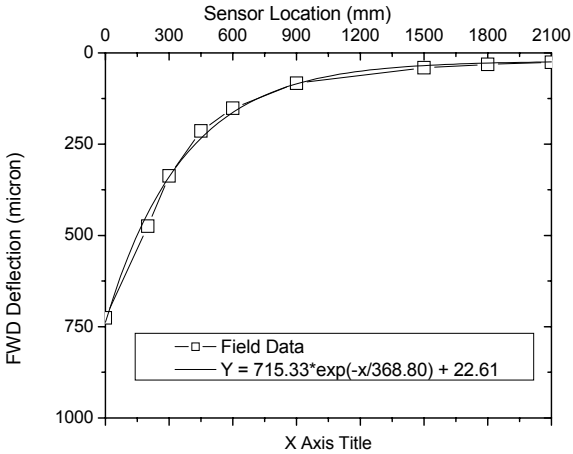


**Figure 9** Deflection at LTPP No: CCC10

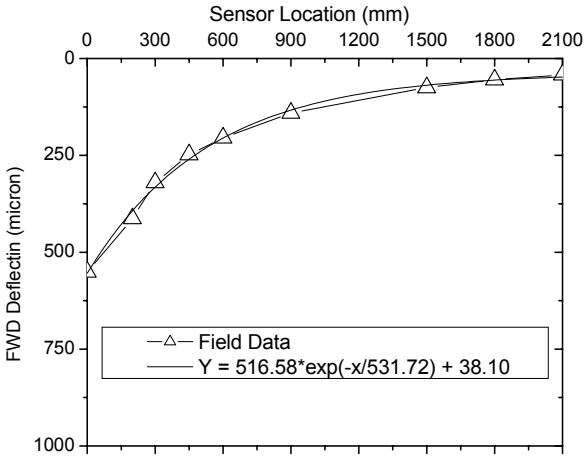


**Figure 10** Deflection at LTPP No: CSC08

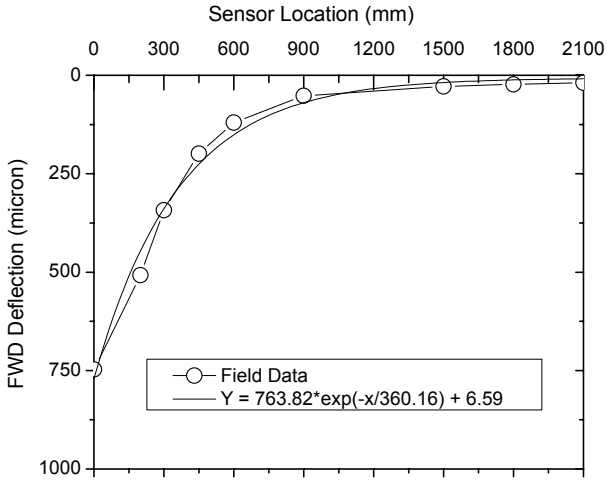


**Figure 11** Deflection at LTPP No: GCC03

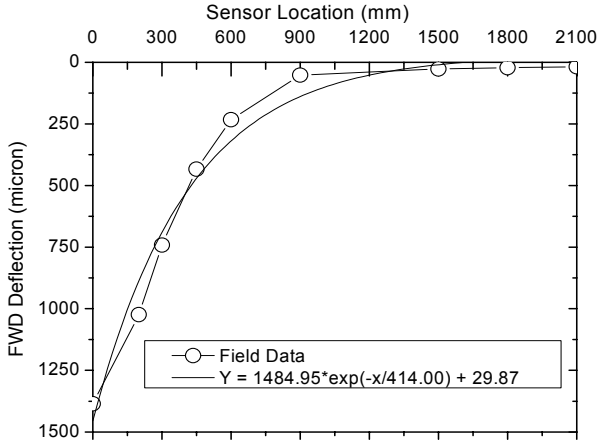


**Figure 12** Deflection at LTPP No: ICC03

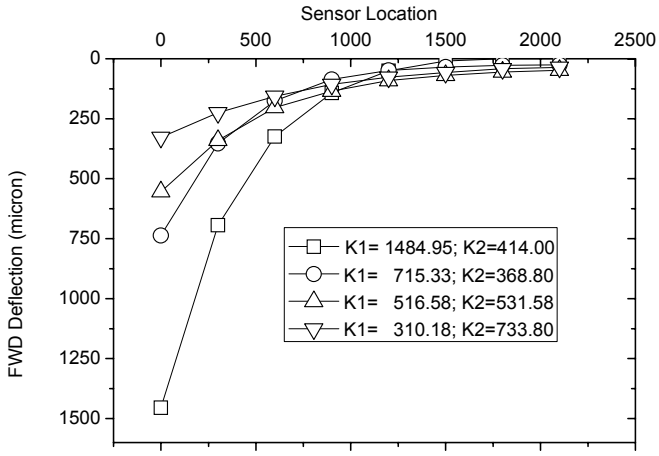


**Figure 13** Effects of parameters K1 and K2 on FWD Deflection

For the current study within the six city and shire councils in southeast Queensland, the pavements were constructed with either thin spray seal, seal coat or asphaltic concrete for relatively low volume of traffic. The surfacing thickness varies from 10 mm to 50 mm and road base layers would range from 150 mm to 400 mm in thickness. From the results presented in **Table 2**, it is clear that the parameter K1 decreases as the stiffness of the pavement road base increases as a result of cement stabilization. Contrary to K1, parameter K2 shows an increasing value for the pavements with stabilized base layers. The study also shows that subgrade strength has a significant influence on the FWD deflection parameter D0 and the structural parameter K1 for low volume road pavements with relatively thin surfacing layers.

**Table 2:** Summary of the K, K and Y defined by the Simplified Deflection Model

| LTPP Site No. | Road Name | K1 | K2 | Y0 |
|---|---|---|---|---|
| RSC05 | Panorama | 408.32 | 385.84 | 7.78 |
| GCC04 | Xanadu Court | 393.04 | 556.59 | 5.82 |
| GCC13 | Larch Street | 310.18 | 733.80 | 18.00 |
| LCC1 | Chambers Flat | 616.90 | 392.23 | 9.35 |
| LCC5 | Watland | 421.41 | 383.35 | 9.56 |
| CCC5 | Queens | 466.18 | 402.05 | 2.06 |
| LCC08 | Lawnton | 608.33 | 318.96 | 13.82 |
| LCC11 | Sport Drive | 491.75 | 567.56 | 14.08 |
| CCC10 | Burys | 715.33 | 368.80 | 22.61 |
| CSC08 | Avon Avenue | 516.58 | 531.72 | 38.1 |
| GCC03 | Dudgeon Drive | 1484.95 | 414.00 | 29.87 |
| ICC03 | Commercial | 763.82 | 360.16 | 6.59 |

## CONCLUSIONS

In this paper, the FWD deflection characteristics for 12 SEQ-LTPP sites were studied using a mathematical model in the form of $Y = K1 \exp(-X/K2) + Y0$. The simplified deflection model was found to have the desired characteristics which match the FWD deflection basins reasonably well. The structural parameters K1 and K2 of the deflection model may be used to evaluate the structural characteristics of pavements.

It is evident that the parameter K1 decreases as the stiffness of the pavement road base increases as a result of cement stabilization. Contrary to K1, parameter K2 shows an increasing value for the pavements with stabilized base layers because of the increase of the stiffness of the road base layer. The study also shows that subgrade strength has a significant influence on the FWD deflection parameter D0 and the structural parameter K1 for low volume road pavements with relatively thin surfacing layers.

An alternative approach in the interpretation of the FWD deflection has been developed in this research study. The structural parameters K1 and K2 of the simplified deflection model may be used to predict the performance of the pavement structures. The results presented in this paper demonstrate the potential application of the simplified deflection model in evaluating the road pavements for the six Local Government Authorities in Southeast Queensland.

With the new approach, it is hope that the destructive tests such as the Dynamic Cone Penetrometer and pavement coring can be reduced thereby minimizing traffic congestion and cost of pavement testing works.

## REFERENCES

1) Chai, G. W., Research and Development Program in Road Management and Technology – The Research Methodology, Griffith University, Gold Coast, Queensland, Australia, 2003.
2) Chai, G. W., Specification for Data Collection for LTPP Study, Griffith University, Gold Coast, Queensland, Australia, 2005.
3) QMR, Pavement Rehabilitation Manual, Pavements and Asset Strategy Branch of the Queensland Department of Transport, June 1992.
4) Austroads, A Guide for Structural Design of Road Pavements, Austroads, Sydney, Australia, 1992.
5) Austroads, A Guide for Structural Design of Road Pavements, Austroads, Sydney, Australia, 2004.