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Sydney Aquatic Centre Roof Drainage Model Tests

Modèle du drainage des toitures du centre de sport aquatiques de Sydney

Modellversuche zur Dachdrainage von Sydneys Wassersportzentrum

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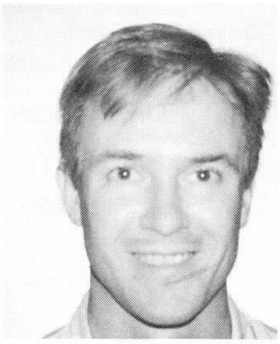

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SUMMARY

This Aquatic Centre, designed for the Sydney 2000 Olympic Games, has a spectator seating capacity of 12' 500 and is covered by a complex roof configuration. A trapezoidal internal metal gutter collects storm water runoff from two roof surfaces (3' 800m2). Supported from above by an external transfer arch, the gutter is designed to convey runoff from a 100 year average recurrence interval storm. Vertical ties from the transfer arch protrude into the gutter floor to obstruct storm water flows. Design features of the roof and hydraulic model tests are described.

RÉSUMÉ

Ce centre de sports aquatiques fait part du complexe projeté pour l'Olympiade de 2000. Le centre offre 12'500 places assises. Il possède une toiture à structure porteuse compliquée. Un chêneau métallique trapézoïdal collecte l'eau de pluie provenant de deux pans de toiture (3'800 m2). Suspendu à un arc porteur extérieur, ce chêneau a été dimensionné pour absorber l'eau de la tempête maximale de 100 ans. Les suspentes de l'arc traversent le fond du chêneau. Les particularités du projet de la toiture et les études hydrauliques sur modèle sont décrites.

ZUSAMMENFASSUNG

Das Aquatic Centre wurde für die Olympiade 2000 mit 12'500 Sitzplätzen entworfen. Die Anlage ist durch ein kompliziertes Dachtragwerk überdeckt. Eine innere trapezförmige Wasserrinne leitet das Meteorwasser von zwei Dachflächen (3'800 m2) ab. Aufgehängt an einem externen Stützbogen, wurde die Rinne für einen 100jährigen Gewittersturm bemessen; die Hängestangen vom Bogen treten im Rinnenboden als Abflusshindernisse hervor. Entwurfsbesonderheiten des Daches und hydraulische Modellstudien werden vorgestellt.

1. INTRODUCTION

Friday 23rd September 1993 will always remain a memorable day for the sport-loving Australian public. For those associated with the Olympics 2000 engineering works the feeling of excitement was even more intense. Over the past two years a 760 ha derelict site at Homebush Bay, 15 km west of Sydney city centre, has been gradually transformed into a futuristic Olympic venue. In particular, innovative architectural, engineering and landscape works have been integrated in the design and construction of the Sydney International Athletic and Aquatic Centres. Most of the work has been project-managed on behalf of the New South Wales State Government by Civil and Civic Pty Ltd, a major Australian contractor. Figure 1 shows the location of the Homebush Bay site.

The original masterplan allowed for completion in either Olympic or non-Olympic mode. In the latter mode the Sydney International Athletic Centre has a 15,000 seating capacity competition arena and warm-up track. In Olympic mode the competition arena becomes a warm-up track and a new 80,000 seating capacity stadium will be built next door.

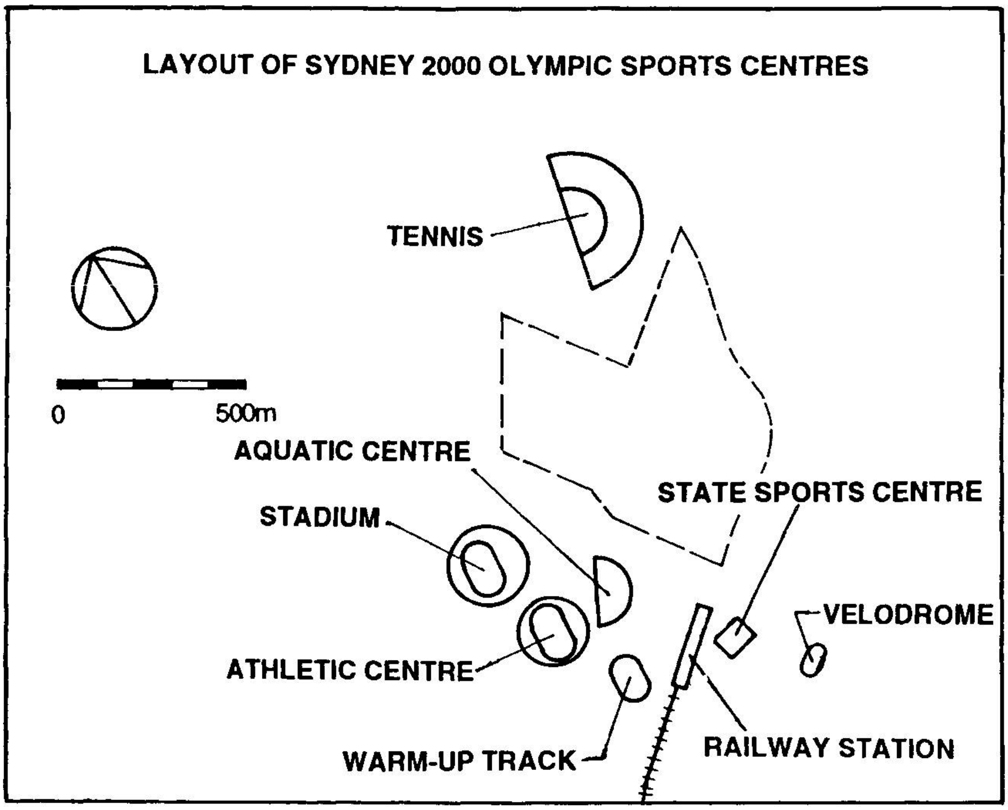

Fig.1 Location and Layout of the Homebush Bay Site

2. SYDNEY AQUATIC CENTRE

2.1 General

The Sydney Aquatic Centre has a non-Olympic seating capacity of 4,400. Additional undercover area will be provided for the Olympic Games, increasing the seating capacity to 12,500. The entire viewing area will be air-conditioned with outlets placed beneath or behind all rows of seating. The Aquatic Centre encompasses leisure pools, a training pool of adjustable depth, a main competition pool of adjustable length and a diving pool. The entire structure is enclosed with a complex roof geometry providing an unobstructed plan space of 120 m by 62 m. A clear height of 13 m is available at the underside of the centre of the roof trusses. In Olympic mode an additional plan width of 25 m is provided on one side.

2.2 Roof System

The main pool area is roofed with an arched truss arrangement. In non-Olympic mode the curved main roof has a plan area of 2,575 m^2. A monoslope roof of plan area 1225 m^2 is provided above the additional Olympic seating area. A line of sight from the uppermost row of seating to the far side of the main competition pool has to clear the junction of the underside of the main and monoslope roof areas. A trapezoidal internal gutter is provided to permit this line of sight. See Figure 2.

The trapezoidal gutter and roof junction are supported from above by an external transfer arch. This arch is constructed of uniform radius steel box section with steel ties supporting the gutter, the curved main roof and the monoslope Olympic extension. The total roof weight is approximately 640 tonnes. The box section arch below the gutter bifurcates, providing both an aesthetically attractive feature and additional lateral stability.

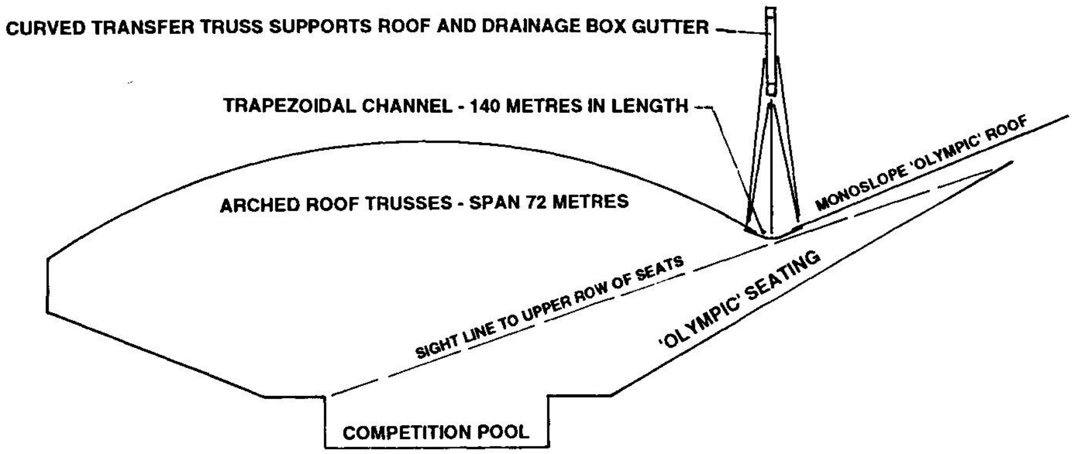

Fig.2 Sydney Aquatic Centre, Elevation View

3. ROOF DRAINAGE

The trapezoidal gutter is supported from above by vertically oriented ties which are streamlined with aerofoil-shaped casings. This design aims to minimise disturbance to the water flow during storm events. An outlet is located at each end of the 140 m long gutter. Each outlet has a steep sloping open channel section, allowing rapid freefall discharge of the stormwater flow.

The large, unusual shaped gutter is designed to convey a 100 year average recurrence interval (ARI) storm. During a storm event the protruding streamlined support tie casings will present obstructions to the flow. The 100 year ARI storm runoff corresponds to flows into the gutter of approximately 3.2 L/s/metre width for the arched roof alone and 4.7 L/s/metre width for the arched and monoslope roofs combined. These are referred to in the model testing as the *low* and *high* flow rates respectively. Note that only a single roof surface was used in the model tests.

Water flowing laterally into a longitudinal open channel flow produces a complex hydraulic regime known as *spatially varied flow.* Current Standards Association of Australia [1] guidelines for the design of internal gutters are based on work conducted by Martin [2] and Martin and Tilley [3]. The analysis of spatially varied flow for roof drainage design is described by Mein and Jones [4] and by Jones and O'Loughlin [5]. Analysis requires the prior knowledge of the effective roughness of the gutter. The flow is termed spatially varied because the flowrate varies along the spatial length of the channel. A complete theoretical analysis is not possible for the Sydney Aquatic Centre gutter because of the disturbances arising from the tie protrusions.

The Project Managers for the Aquatic Centre, Civil and Civic Pty Ltd, commissioned the University of Technology, Sydney (UTS) to conduct model testing in order to establish whether the unique gutter shape, and unorthodox overhead support structure could safely collect and discharge runoff from the design storm. UTS were at the time conducting full-scale experimental roof drainage tests for the Standards Association of Australia. These tests are described by Beecham and O'Loughlin [6].

4. HYDRAULIC MODEL

For a design rainfall intensity of 313 mm/hour, the model was required to estimate the depth of flow on the roof sheeting and the maximum depth of flow in the trapezoidal gutter, assuming a free outfall. The effect of tie protrusions on the maximum gutter depth was also investigated. The 9 m long model gutter was built full-scale (1:1). The model roof and gutter configurations are shown in Figure 3. It was not possible to model an arched roof in the laboratory. To obtain a conservatively high estimate of prototype gutter depth a plane roof was used, inclined at the maximum slope of the arched structure. One disadvantage with this configuration was the likelihood of underestimating the maximum water depth on the roof sheeting. This was not considered critical in light of the very shallow depths measured on the model roof sheeting.

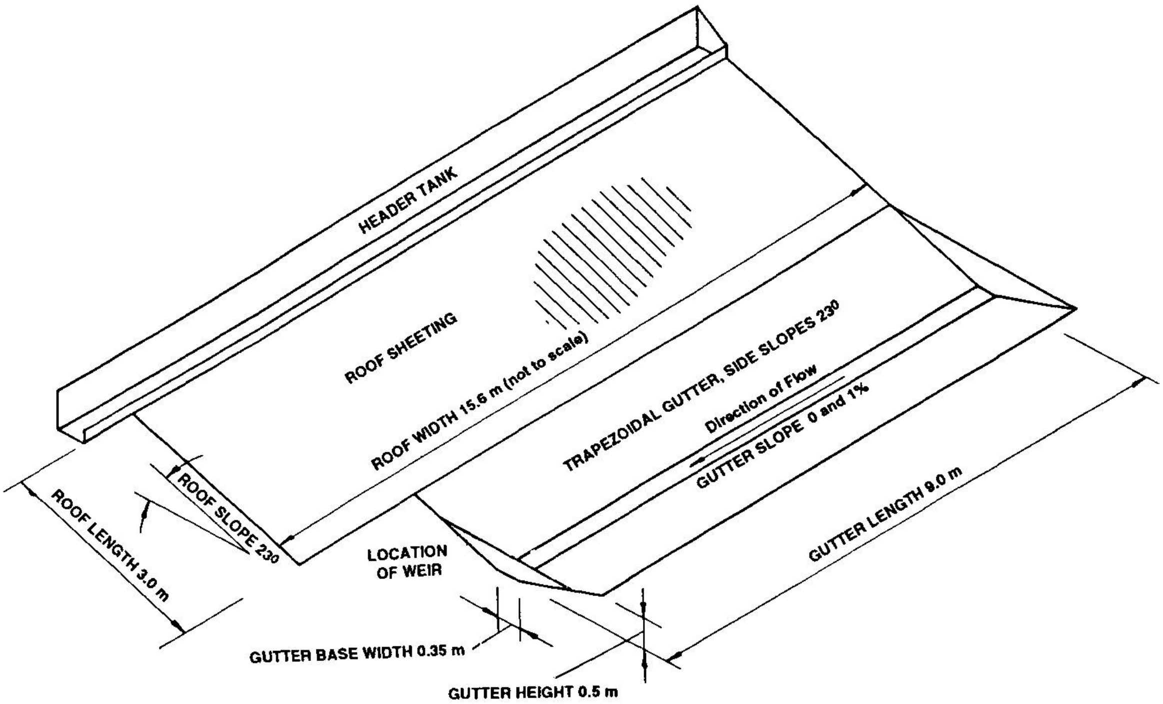

Fig.3 Model Roof and Gutter Configuration

Depth profiles were measured in the horizontal trapezoidal gutter for both the low (3.2 L/s/metre width) and high (4.7 L/s/m width) flowrates. The flows were supplied using a header tank suspended along the full length of the model roof, shown in Figure 3. Two further tests were conducted using the same gutter with a 1% fall. All leakage losses were collected and passed through a calibrated V-notch weir. For all tests the losses were found to be less than 0.1% of the flow rate. In both tests a free outfall was assumed at the downstream end of the prototype gutter. To model the effects of half the 140 m long prototype gutter, a transverse sharp-crested weir, with a sill height of 379 mm, was constructed at the downstream end of the model gutter. To ensure that the weir had no end effects on the measured flows, the roof discharge was restricted to the upstream 5 m of the model gutter, located 4 m to 9 m from the weir. It was calculated that this weir generated depths of flow in the model equal to those in the prototype gutter. Other assumptions were that rainfall impact and wind turbulence would not significantly affect the flows, and that the roof flow was fully established over a three metre length. Each roof and gutter configuration was tested for the effect of a tie member protrusion located at various positions along the gutter.

5. RESULTS

5.1 Depth of Flow on Roof Surface

The depth of flow on the model roof was independent of the gutter configuration, and was only influenced by the flow rate. Figure 4 shows the average measured depths of flow in the Alcan LT7 roof sheeting pans for the two flow rates. It was concluded that, for the steepest roof slope of 23° the sheeting profile was adequate to convey the design flowrates. Note that it was not possible to model raindrop impact and wind effects.

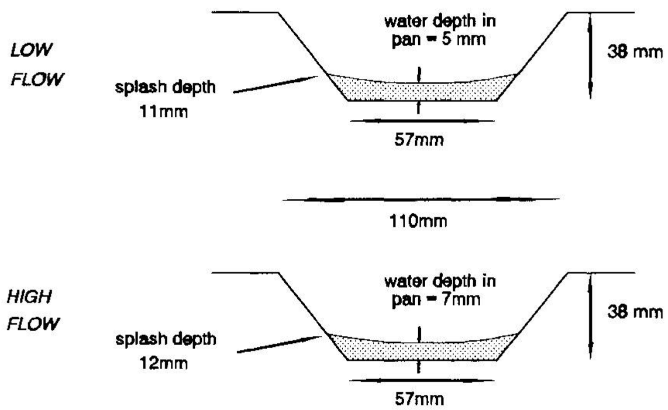

Fig.4 Depths of Flow on Roof Sheeting

5.2 Gutter Depth Profiles

Average depths of flow, relative to the channel floor, were measured at 0.5 m intervals over the full 9 m gutter length. The lateral inflow from the roof surface was restricted to the upstream 5 m of the gutter (corresponding to the range 4 to 9 m from the weir on the following graphs). Only the depths in this 5 m length are indicative of the prototype depths.

For a horizontal gutter, the maximum measured depth of flow was 417 mm (see Figure 5) which occurred with a tie protrusion located 6 to 7 m from the downstream weir. For a gutter with a 1% fall, the maximum measured depth of flow was 375 mm (see Figure 6). This occurred with a tie protrusion located 4 to 5 m from the downstream weir. The flows are spatially-varied and the location of the maximum depth will alter with gutter slope. Therefore it is not possible to directly interpolate these results for gutter slopes between 0 and 1%.

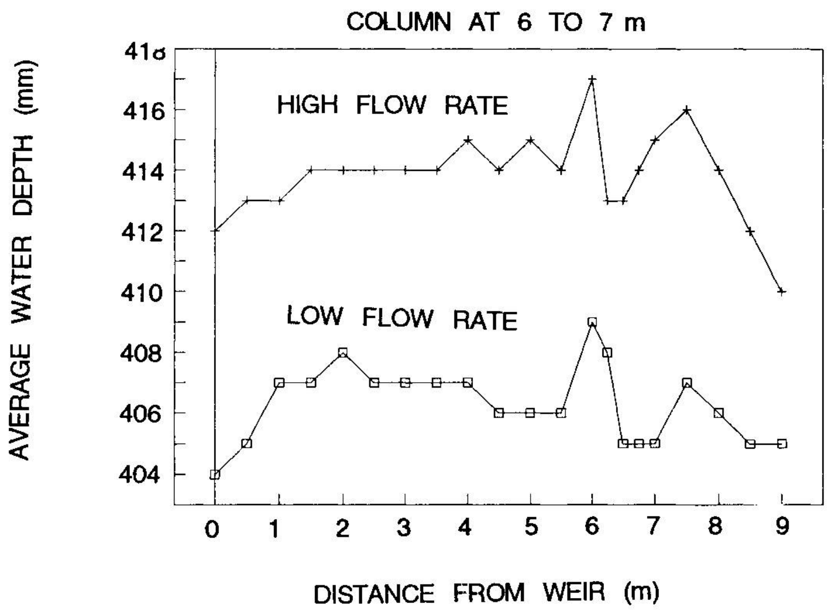

Fig.5 Horizontal Gutter

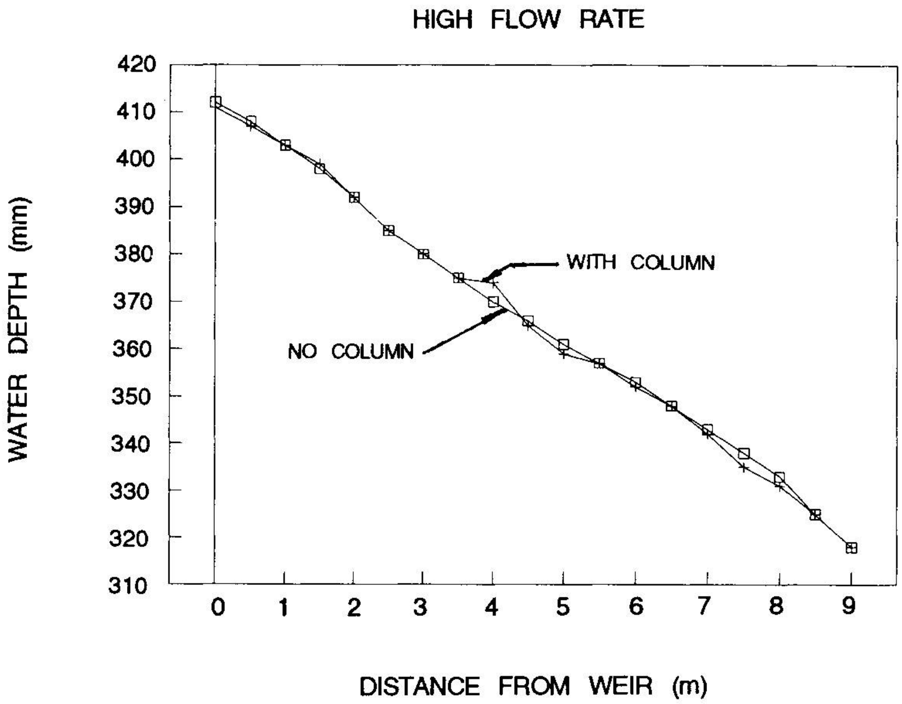

Fig.6 Sloping Gutter (1%)

6. CONCLUSIONS

From the results of the model testing program both the Alcan LT7 roof sheeting profile and the wide trapezoidal gutter designed for the Sydney Aquatic Centre have sufficient capacity to safely drain the roof runoff corresponding to a 100 year average recurrence interval storm. The streamlined casings of the tie protrusions from the overhead support truss do not significantly affect the water depths in the trapezoidal gutter.

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