

ADVANCES IN CONCRETE PLACEMENT METHODS AND FINISHING TECHNIQUES FOR HIGH PERFORMANCE INDUSTRIAL PAVEMENTS IN AUSTRALIA

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ABSTRACT

The quality and overall performance of concrete industrial floor slabs has improved dramatically as a result of technological advances in concrete supply, placement methods, the finishing process, curing and joint sealants. Placement and finishing techniques have improved substantially in recent years with larger area pours now resulting in a reduction in construction time. Client expectations for a high quality, hard wearing concrete industrial floor slab with long term performance and minimal maintenance costs has become the norm. Both designers and contractors now require specialised expertise to achieve these results. In order to improve the quality of industrial floors it has been necessary to establish working relationships between engineers, developers and the concrete contractors. This close relationship allows communication between the parties and provides a mutual understanding of all the issues associated with the design and construction methods to be employed.

KEYWORDS

High performance pavements, Vibrating screeds, Laser screeds, Scraping straight edges, Bump cutters, Ride on helicopters, Panfloats, Burnish finish, Surface tolerances, Flatness and Levellness.

INTRODUCTION

This paper reviews the most current practices in Australia for construction of high performance industrial pavements. The different floor pouring / placement methods associated with fabric reinforced, steel fibre reinforced and post-tensioned designs are highlighted together with levelling techniques and the degree of burnish finish achieved. The paper investigates through a series of six case studies, a comparison of construction methods and pour types including, long strips, double width strips with removable rails and large area pours together with floor tolerances.

The size of the pour areas and shape thereof often predetermine the choice of both the vibrating screed equipment and trowelling equipment necessary to achieve the slab finish required whilst maintaining surface tolerances. The case studies represent a variety of pour sizes and shapes and indicate the

selection of equipment used by a range of specialist concrete. The paper concludes with a “Table of Characteristics and Comparisons” with an indication of future directions, developments and trends.

CONSTRUCTION TECHNIQUES & EQUIPMENT

Pouring Methods

- Pour widths, pour lengths, and the set up of reinforcement once documented and detailed, usually predetermine the concrete placement method.
- Direct placement from the truck for low slump, low shrinkage concrete.
- Reinforcement chaired up and inspected prior to the pour, but direct placement not possible.
- The alternative is to chair up reinforcement progressively but cover is suspect.
- Hence the advantage of steel fibre reinforced slabs.
- Concrete pumps with placement booms provide an efficient method of placing concrete for both post-tensioned and steel reinforced slabs when the reinforcing has been set up prior to the pour.
- However, with limited roof heights, the horizontal reach of placement booms is limited.

Established Levelling Techniques

- The plan shape and pour area size has a major impact on the levelling techniques used during construction. The traditional “Long Strip” layout requires accurate set up and levelling of the edge formwork with hand screeds or mechanical beam type vibrating screeds used to level the surface.
- Double width long strips with a removable intermediate rail are more efficient since the pour area can be doubled and construction time thereby reduced. Removable rails can also be used on large area pours.
- Large area pours with dimensions in excess of 25m (approx.) in each direction can be levelled by taking spot levels (optical or laser) on the concrete surface at regular grids (up to 3.6m) and then power floated between the spot levels. Floor tolerances expected with this method of construction are perhaps + or – 4mm in 3.0m at best. The alternative would be to use a removable intermediate rail which would require the vibrating screeds to span 12.5m (their upper limit) and floor tolerances would be unlikely to be improved. To achieve higher levels of flatness and levelness a laser guided hydraulic driven mobile cutting and vibrating screed can be used.

Slab Specifications for Finish & Tolerances

- Various trowelling techniques are used to produce either a light, medium or heavy burnish finish. Early trowelling with panfloats followed by trowelling with the standard blades and continually working the surface over an extended period which results in a hard wearing, abrasive resistant, burnish finish, (often referred to as “black concrete”).
- Australian specifications typically call for a slab to be constructed within + or – 3mm in 3.0m with a cross fall not compounding over 10m and not to exceed 5mm from RL and a differential across all joints of + or – 1mm maximum. More recently however, larger buildings have been specified using the “ American Standard Specifications for Tolerances for Concrete Construction and Materials, ACI #117R-90 “. This covers the specification and measurement of F_F (floor flatness) and F_L (floor-levelness) values for concrete slabs.

Equipment Overview

The equipment used and the procedures to be adopted for placement, screeding and finishing varies significantly from contractor to contractor in accordance with their available equipment, crew size, quality of surface finish required, their expertise and their specialisation in constructing particular pour area types. Recent improvements in placement, finishing methods and concrete technology have

allowed the pour size and joint spacing to be increased without comprising finish, flatness or overall cost. The range of equipment currently used includes:

- Optical and laser levels
- Hand screeds
- Power trowels (magic screeds)
- Scraping straightedges and bullfloats
- Mechanical vibrating screeds, solid steel sections or truss type vibrating screeds
- Laser guided hydraulic driven mobile cutting, levelling and vibrating screeds
- Pan floats (pizza pans) for walk-behind and ride-on trowels
- Single blade walk behind helicopter trowels , double and triple blade ride ons

CASE STUDIES

For comparative purposes, the project highlights were covered in the following order:

- Project description / pour areas
- Specifications / floor finish and tolerances
- Concrete placement method
- Screeding and levelling techniques / equipment
- Trowelling equipment / finishing / duration
- Difficulties experienced and comments

Each case study is complimented by two digital images which highlight the specific project features.

1. “Country Road ” Clothing Distribution Warehouse

- The total floor area of 5,200 m² was divided into 18 long strip pours each 50m long by varying widths up to 5.85m. Pouring commenced on completion of the exterior cladding with areas up to 290m² per pour. This was the first burnish finish fibre reinforced slab constructed in Victoria.
- A hard wearing burnish finish was specified for both the racking and order collation areas. Tolerances were specified at + or – 3mm in 3.0m with a cross fall no compounding over 10m and not to exceed 5mm from RL with + or –1mm across joints. The constructed slab met these requirements and was checked using an “F meter “ at F_F 70 and F_L 40.
- The concrete was placed direct from the truck chute, having reversed down the long strips.
- Truss type vibrating screeds were used and traversed the length of the strip. Edge formwork comprised of timber with a 50 x 4mm steel flat nailed vertically onto the timber so that the top edge was some 10mm above the timber. Optical levels to within 2mm were taken at 900mm centres along the steel edge. A 2.4m wide bump cutter was used across the strips to remove any surface irregularities.
- Twin blade ride-on power trowels commenced early with panfloats, followed by approximately 4 hrs. of helicopter blade trowelling with the blade angle progressively increasing as time passed. At this stage the concrete was quite dark in colour, characteristic of a burnish finish. The machines were equipped with two containers of aliphatic alcohol (a set retarder), which was sprayed onto the surface to adjust non-uniform setting rates. A chlorinated rubber spray on curing compound was applied immediately after the trowelling had ceased. The typical 290m² long strips took on average 9 hrs. to complete.
- Some steel fibres were exposed on the surface with occasional fibre tearout at the saw cut joints. The combination of a relatively dry mix design and the fibre reinforcement made the concrete difficult to work.

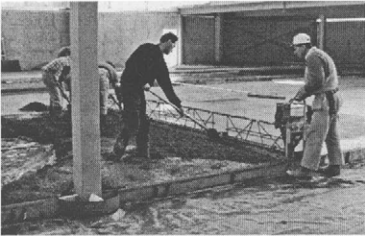


Figure.1 Truss vibrating screed, FRC slab

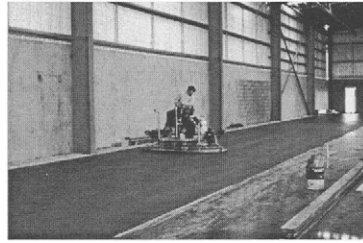


Figure.2 Ride on power trowel, long strip

2. “QP2” A Supermarket Chain High Bay Warehouse and Distribution Centre

- The warehouse comprised a 9 storey high bay racking system with a 500mm thick ground slab to support the superstructure. This slab covered 7,730m² and was poured in 8 stages, covering 46m x 168m with each pour approximately 23m wide x 42m long (966m²). The “distribution centre” slabs were 180mm thick and post-tensioned. This area covered some 15,200m² in 8 adjacent pours each approximately 38m x 50m ,(1,900m² each pour).
- The above slabs were specified to have a hard wearing burnish finish. Tolerances were specified at + or – 3mm in 3.0m with all levels not to exceed 5mm from RL. (Achieved F_F 50, F_L 40)
- Both slab types were poured using concrete pumps with placement booms. The post-tensioned slab of 1900m² required the use of 2 pumps and 2 vibrating screeds.
- Double and triple width pour strips were necessary to screed these large areas. Truss type vibrating screeds were used in both cases, each utilising removable rails set to the correct height / levels. The rails were removed on completion of the screeding and localised rectification works done. The screeds spanned up to 11.5m to achieve the pour widths required. Optical levelling of the supporting steel edge piece to within 2mm was done at 1.2m centres. Long handle 3.0m wide scraping straightedges were used in the transverse direction to take out surface irregularities.
- The post-tensioned slab required the use of two, twin blade and one, triple blade ride-on power trowels and several walk behind machines . Early panfloat trowelling was followed by 3 hrs. of helicopter blade trowelling which achieved the light burnish finish as specified. Each slab pour required a double size crew with an average 14 hrs. to complete
- A continuous supply of concrete for the 500m³ “high bay “ slab pours, often extended the completion time. Concrete placement and vibration was difficult with closely spaced large diameter reinforcing bars in both the top and bottom of the 500mm slab. Cold and windy conditions extended the trowelling requirements.



Figure.3 Removable rails, double width strip

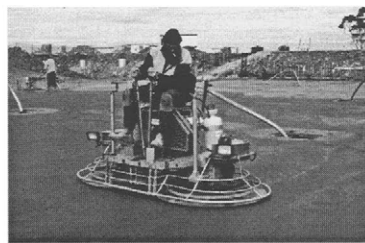


Figure.4 Initial trowelling with panfloats

3. “Chiffley Drive” Paper Distribution Warehouse

- A combination of reinforced and post-tensioned concrete designs with total floor area of 12,000m². Reinforced slabs 250mm thick poured in long strips from 9.0-13.5m wide with saw cuts on 6m x 4.5m grid and maximum pour area 785m². Post-tensioned slabs 180mm thick with ducts at 1500mm crs. each way with both movement and construction joints. Maximum pour area 2088m².
- The slab was specified to be a hard burnish finish with floor tolerances of + or - 4mm in 3.0m and not more than 5mm from datum. Achieved + or - 3mm in 3.0m.
- Concrete was placed using 2 placement boom concrete pumps with 2 separate concrete crews.
- The concrete was compacted with immersion vibrators, roughly shovelled level and then spot optical levels taken to suit the power float (magic screed) with a 3.6m blade utilised to screed and float the concrete surface. Permissible floor tolerances made this screeding and levelling technique more economical and faster in contrast to using long hand screeds. A long handle 3.6m wide scraping straightedge was used in the transverse direction.
- 4 walk behind power trowels with panfloats commenced at 5 hrs. and were followed by up to 5 twin blade ride-on power trowels with helicopter blades and pans. With 2 concrete crews of 8, the final trowelling ceased at 12 hrs. with a spray on curing compound applied immediately thereafter.
- The slabs was completed with a large concrete crew utilising basic equipment as the slab tolerances were not difficult to achieve. Optical levels were taken over distances up to 50m.



Figure.5 Power float, large area pour



Figure.6 Two concrete pumps, optical levels

4. “Penguin Books” Warehouse

- The slab was redesigned to a steel fibre reinforced slab 180mm thick. The total floor area was 21,000m² poured in 21 stages on a 3 wide x 7 long grid pattern. Pours in the 11m high racking area were 870m² each (28m x 31m)
- A hard wearing burnish finish was specified. Floor tolerances were specified by the supplier of the man-up turret trucks (14m lift). The specification required a 6mm maximum difference in elevation of any 2 points 2.4m apart in the direction of truck travel and a 2mm maximum difference in elevation of any 2 points across the aisle at the outside of the load wheel path. There was a 1.5mm maximum difference in elevation of any 2 points 300mm apart in the load and steer wheel path. An F_F 50 slab was considered adequate to meet these requirements. Over the 9 areas poured in the high rack area, the averages achieved were F_F 70 and F_L 60. A comparative optical level grid survey was carried out at 2m centres with < 2mm variance.
- The fibre reinforced concrete was placed directly from the chute with two trucks being able to discharge at once.
- A Somero laser screed was used to cut, screed and vibrate the concrete. A uniform head of concrete in front of the screed was no longer required and the screeding time was significantly less, resulting in substantial labour savings and the ability to level / screed much larger areas of concrete. Long handle 2.4m wide scraping straightedges were used in the transverse direction to take out surface irregularities. Edge formwork was checked with a laser level at 1.5m centres.

- Two walk behind and two ride-on power trowels were used to finish the slab. Initial trowelling with panfloats commenced 4 hrs. after the first concrete delivery. At 6 hrs. the pans were removed and helicopter blades continued with the slab starting to burnish up at 7hrs. The slab was completed at 9 hrs. and sprayed immediately with a curing compound.
- The concrete was placed with a 28m wide working face (the full width of the pour) which created some relatively cold faces when there were delays in truck deliveries. This had a direct effect on the trowelling and subsequent work required on the slab surface where fresh and older concrete occur, side by side. Consistent concrete deliveries and uniform setting rates must be maintained. With 6 pours per week, the concreter's progress was restricted by the slower progress of the roof and wall cladding.

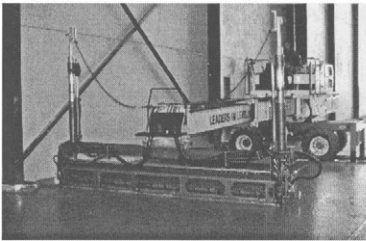


Figure.7 Somero laser screed, large area pour

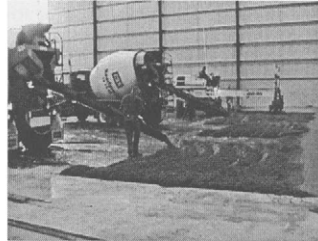


Figure.8 Direct concrete placement

5. “Tsusho” Toyota Spare Parts Warehouse

- This fabric reinforced concrete slab 175mm thick covered an area of 25,000m² and was poured in 24 stages. The pours were approximately 34m long x 30m wide (1020m²).
- Tolerances specified at + or - 3mm in 3.0m, within + or -5mm from RL and 2mm differential across joints. An optical survey on completion indicated slab tolerances were within 1.5mm.
- Placement was by concrete pump with a hydraulic boom arm and required two set up positions to cover the area. Two trucks fed the concrete pump.
- Levelling completed by laser screed set up on ladder tracks which were supported on large 4 legged stools which neatly fitted in between the reinforcing mesh grid. A long handle 2.4m wide scraping straightedge were also used. Achieved F_F 60 F_L 50 tolerances.
- Walk behind and ride-on power trowels with panfloats and blades completed the hard burnish finish within 11 hrs.
- Each slab pour area was softcut sawed at 8 hrs. to a depth of 40mm to divide the area into 4 panels. Danley flat plate dowels 50 x10 at 600mm crs in prefabricated cages were located under these saw cuts with a 55mm high crack inducer detailed. At 24 hrs. the joint was recut to 50mm and additional cuts made to reduce the panel areas to 7.5m x 5.6m. Pour joints were constructed with Danley 6mm thick diamond plate dowels at 600mm crs.

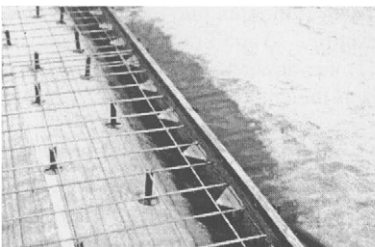


Figure.9 Danley diamond dowel joint

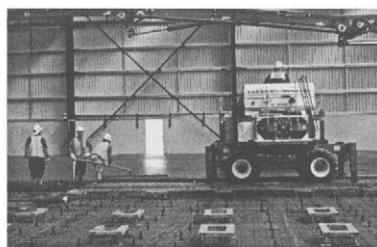


Figure.10 Laser screed, ladder rails & stools

6. “Toll Holdings” Transportation Distribution Warehouse

- The total floor area covered $31,680\text{m}^2$ and was poured in 20 stages on a 2 wide x 10 long grid pattern. Each pour measured approximately $36\text{m} \times 44\text{m}$ ($1,584\text{m}^2$). The slab was 160mm thick post-tensioned with ducts at 2.1m centres each way. On completion of the stressing, the 900mm wide edge strip between the slab and external precast walls was poured.
- The specification was extremely brief and called for a standard burnish finish. Floor tolerances were specified at minimum F_F 50 and F_L 40. After each pour, an “F” meter was run over the floor in lines around the perimeter. Average readings for the slabs completed were F_F 62 and F_L 50.
- The slabs were poured using a concrete pump with a placement boom. The hydraulic arm could not reach beyond 27m, so 9-10m of flexible rubber pump hose supported on timber blocks had to be attached to the end of the pump arm in order to reach the 36m wide pour.
- Screeding and levelling was done using a Somero laser screed. Heavy duty aluminium removable ladder rail tracks were set up on stools above the tendon ducts, these extended the full width of the pour and included a ramp section to pass over the edge formwork. A long handle 3.6m wide scraping straightedge was used to smoothen out minor surface irregularities. The laser screed used two passes to achieve the tolerances required. Timber edge formwork had a 30 x 5 steel edge plate nail fixed at 450mm centres and checked for level at 1.2m centres using a laser level with circular bubble on the staff.
- Three, twin blade ride-on power trowels were used to finish the slab. Initial trowelling with panfloats commenced 4.5 hrs. after the first concrete delivery. At 6.5 hrs, helicopter blades were used with the slab starting to burnish up at 8hrs. The slab was completed at 13 hrs. with a crew of 12. “F” meter readings were taken prior to the slab being sprayed with a curing compound.
- Additional immersion vibrators were required to ensure adequate compaction of the concrete under the tendon ducts (normally the laser screed is sufficient). Setting up the 10m of rubber hose extension to the pump slowed down the concrete placement process.

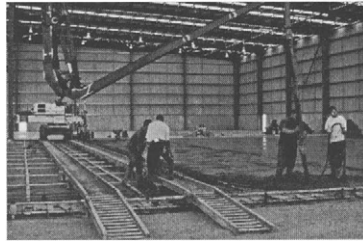
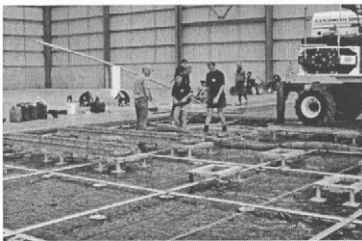


Figure.11 Laser screed on post-tensioned slab Figure.12 Ladder tracks & concrete pump

SUMMARY & CONCLUSIONS

The concrete contractors in Australia, have in recent years, imported a wide range of equipment best suited to meet their own specialised construction method. The variety of equipment purchased, enables the contractors to meet the surface finish and surface tolerance specifications particular to their market sector. There remains significant market segmentation within the industrial ground slab concrete industry. This is particularly noticeable with those contractors who have imported expensive laser screed equipment and now only construct large area pours to F_F and F_L requirements / specifications.

The six case studies represent a range of slab pour types, levelling and finishing techniques adopted in Australia, but it is still primarily the engineer who dictates the pour area / layout. Pour areas around or in excess of 1000m^2 are becoming the norm with the traditional large concrete crews being replaced by the use of laser guided screed equipment. A summary Table 1. follows.

Table 1.
Characteristics & Comparison of Case Studies

CASE STUDY NO.	TOTAL FLOOR AREA SQ.M.	CONC. POUR AREA SQ.M.	POUR TYPE/METHOD	SLAB DESIGN	PLACE- MENT METHOD	TOLER- ANCES (Achieved)	SURF- ACE FINISH	LEVELS & SCREED TYPE	TROWEL METHOD & FINISHING
1	5,200	290	Long strip	Steel fibre	Direct from truck	3mm/3m 5mm RL 1mm joint (F _F 70 F _L 40)	Hard burnish	Optical Truss vibrating screed	Ride-on panfloats Ride-on blades
2	7,730	966	Double strip	Steel rein.	Concrete pump	3mm/3m 5mm RL (F _F 50 F _L 40)	Hard burnish	Optical 2 Truss vibrating screeds	Ride-on panfloats Ride-on blades
3	12,000	2,088	Large area	Post-tension & Steel rein.	Concrete pump	4mm/3m 5mm RL (3mm/3m)	Hard burnish	Optical Power floats	Ride-on panfloats Ride-on blades
4	21,000	870	Large area	Steel fibre	Direct from truck	F _F 50 F _L 40 (F _F 70 F _L 60)	Hard burnish	Laser Laser vibrating screed	Ride-on panfloats Ride-on blades
5	25,000	1,020	Large area	Steel rein.	Concrete pump	3mm/3m 5mm RL 2mm joint (F _F 60 F _L 50)	Hard burnish	Laser Laser vibrating screed	Walk behind panfloats
6	31,680	1,584	Large area	Post-tension	Concrete pump	F _F 50 F _L 40 (F _F 62 F _L 50)	Standard burnish	Laser Laser vibrating screed	Ride-on panfloats Ride-on blades

COMMENTS ON TABLE 1. Characteristics and Comparison of Case Studies

Although there is no correlation between tolerances specified in (mm/3.0m and within RL) to (F_F and F_L) tolerances, measurements and verification of actual tolerances achieved are normally carried out over the slabs using an “ F “ meter.

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