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Combined Reinforcing - The Right Solution for Container Parks and Other Heavy Duty Pavements

Craig Roberts
Business Development Manager BOSFA Pty Ltd

ABSTRACT

Combined Reinforcing is fast becoming recognised and proven as the right solution for Container Parks and other Heavy Duty Pavements. In these sorts of pavements the first areas that are prone to breaking down or requiring maintenance under the very high loads that are being applied are often the joints and saw-cuts, so introducing a combination of steel fibres and reinforcing mesh can eliminate the need for them. Why both? It is very difficult to achieve a long lasting durable concrete pavement in an economical solution when only using one type of reinforcing, by using a high performance steel fibre and conventional reinforcing steel we can utilise the benefits of both to achieve that desired solution economically.

This paper talks a little about the design methodology behind the combined reinforcing solution, the applications and benefits of it, and will showcase a number of local projects constructed over the past few years.

Introduction

Concrete is a brittle material and cracking will occur. In fact the reinforcing, of any type, is not doing anything until the concrete cracks, it's how we deal with that cracking that is important. If these cracks are controlled within specified levels for the particular application, they are not detrimental to the structural integrity or the serviceability of the structure. In more conventionally reinforced concrete this control is achieved by providing a suitable percentage of steel reinforcing and providing joints as required.

A major design consideration for any structure is the location of those joints, and the associated detailing of them. For very heavily loaded pavements this can become very critical, as they will usually be the first areas prone to breaking down or requiring maintenance, so the objective is to remove them from critical paths and minimise them as much as possible.

Continuously reinforced concrete pavements (CRCP) are a good example of this, as they are designed to eliminate the need for joints, rather than the alternative option of close centred crack control joints, but they do require a lot of steel to keep the inevitable cracking within acceptable limits.

Most slabs and pavements are designed and detailed to limit the stresses induced by restraint, temperature, and shrinkage, ensuring that it remains less than the tensile capacity of the concrete, so it is theoretically designed to remain uncracked. However that also puts fairly prescriptive limitations on the slab shape and size.

More recently innovation in the design of concrete elements has led to the development of design rules and standards that allow for the use of steel fibre reinforced concrete (SFRC) in combination with conventional reinforcing to make it possible to design an economical solution for controlled cracking under serviceability stresses. So now we can design a slab or pavement of any shape or size, which can also be completely joint free.

Eliminating or Minimising Joints

Very heavy loads, such as those being applied to container parks and other heavy duty pavements, often 110 tonne axle loads and 5 high stacked containers, themselves, restrain the concrete significantly increasing the stresses. And if the pavement is pinned in any particular location, any typical movement joints that might otherwise be suitable are now limited in their effectiveness. If those movement joints are not able to work as they are designed to, which is to take up the shrinkage and allow for movement in the slab, then it is inevitable that the slab will crack at some location, and more often than not it will be a dominant crack that has not been designed for, potentially reducing the serviceability and longevity of the slab.



If we eliminate or minimise those typical movement joints, we are not eliminating the shrinkage or movement in the concrete, it still needs to be taken up somewhere. By instead designing that shrinkage and movement to be taken up at much closer centres throughout the pavement, rather than at greater centres, then the width of those joints, now micro-cracks, will be much finer and can remain serviceable in the pavement. In turn by keeping them as fine in width as suitable for each application, they are far less likely to deteriate and require maintenance.

This approach can certainly be difficult to grasp initially, most designers, and even more so end users, have been brought up trying to avoid cracks in their slabs and pavements, believing that cracks are bad! But that's not the case if they are designed for and controlled correctly, cracks can be good! But it is crucial to design them correctly for each required application, and this can only be done with the right high performance steel fibre and the right amount of conventional reinforcing steel. A pavement still needs to be designed in ULS to carry the applied loads, then an SLS design needs to be carried out to ensure that the serviceability requirements are being met.

Crack widths for serviceability will vary depending on the particular application and there are guidelines available for consideration. If the concrete is required to be water tight then a much thinner crack width will be required than that for a typical trafficable pavement with only pneumatic tyres. For container parks a nominal design crack width of about 0.25mm is often preferred, due to the very heavy loads.

Some Design Considerations

Whilst this paper doesn't go into the full detailed design methodology, there are some points that are worth noting. And some that again require a little different way of thinking.

It is very important to understand the application, and what you are looking to achieve. Is it actually necessary to go to a combined solution, or will a fibre only solution be more suitable and more economical? Is it actually restrained, or is it relatively lightly loaded and you just want to minimise the joints? Does it need to be water tight, or need to withstand chemical penetration? Is it an awkward shape, that wraps around a building or something else? Does it have multiple penetrations in it? And of course, what are the applied loads?

Detailing for the restraint, and at re-entrant corners is still extremely important, and consideration needs to be given to the pour layout and schedule.

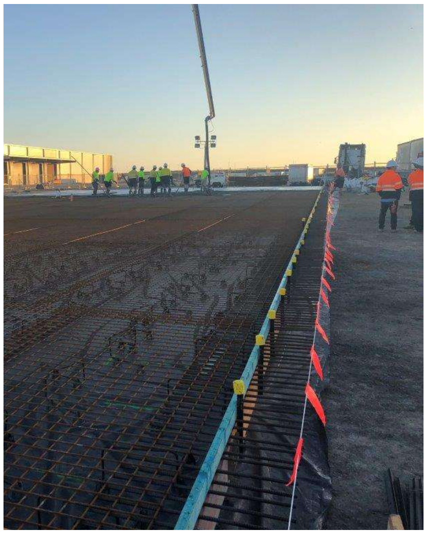
Often the most difficult to comprehend is the accuracy of your concrete strength and slab thickness. Whilst it would seem that actually receiving a higher than ordered concrete strength on site would be a bonus, for a combined reinforced concrete design this is not the case. An increase in concrete strength will require an increase in the percentage of steel, so the reinforcing mesh or bar, to match the concrete stresses. And an increase in slab thickness would similarly be seen as a bonus on site, however this can also require an increase in steel percentage. And more importantly, as the bar chairs won't change in height, it usually results as an increase in cover to the reinforcing steel, which in turn means that the cracks are arrested by that steel at an increased depth potentially resulting in an increase in the nominal crack width at the surface.

These are just a few of the design details that should be considered, and you don't want to get them wrong.

1. Change in pour sequence created differential shrinkage without trimmer bars to compensate.
2. Slab under-designed in ULS for applied loads creating dominant cracks from point loads.
3. Re-entrant corners around pit not trimmed adequately.

Tied or Stitched Joints

Practicality would dictate that an entire container park pavement cannot possibly be poured all at once, so there will be a requirement to stop the concrete at some point and return to continue the concrete pour the next day or soon after. In this situation we are again avoiding the use of more typical movement joints, and instead are designing them as a Tied Joint or Stitched Joint. Essentially we are looking to replicate the designed crack width for the rest of the pavement at this location, just in a straight line. As there will be no steel fibres crossing the crack or joint at that location, we are unable to consider them in the design there, so we need to increase the amount of conventional steel across that crack or joint locally to ensure the same crack width design.



Some of the Many Local Projects Constructed in the Past Few Years

There have now been millions of square kilometres of Combined Reinforced Concrete Slabs and Pavements constructed around the World, and here in Australasia we have more than our fair share. Following are examples of just some of the heavy duty pavements constructed in Australia and New Zealand in the past few years.

IPS Logistics – Port of Brisbane, QLD

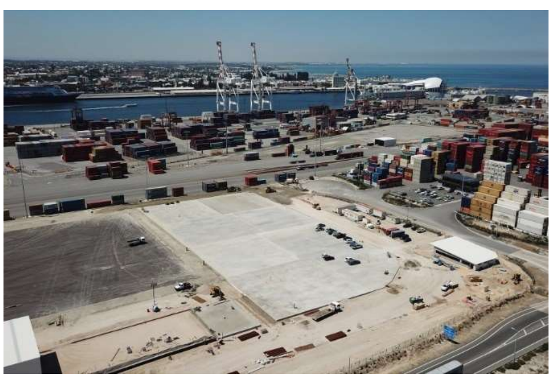
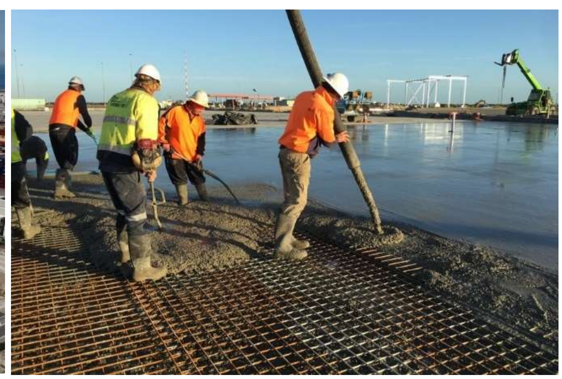
10,000m2 completely Seamless hardstand. Designed to accommodate 5 high stacked containers and 110 axle load forklifts, the most suitable solution to provide a long lasting and durable pavement with minimal future maintenance, was a 325mm thick slab reinforced with a typical dosage rate of steel fibres combined with top reinforcing mesh. By only requiring top mesh to be installed, rather than top and bottom reinforcing bars, or post-tensioning strands, and the concrete being delivered to site with the steel fibres already in the mix, construction time for the project was minimised, allowing for it to start operating in a very short timeframe.

Northline – Regency Park, SA

27,000m2 of heavy duty external pavement. A combined reinforcing solution was chosen to eliminate all joints and saw-cuts throughout the entire pavement, which wrapped around the building, and allowed for a more efficient design.

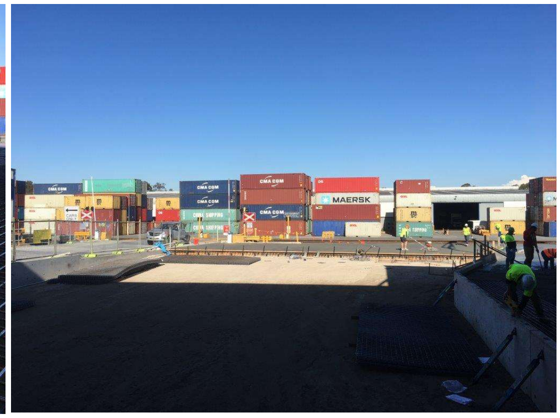
ACFS (Australian Container Freight Services) – Perth WA

The owner of this facility knew that the concrete pavement was the life line of the operation, and once in operation repairs and maintenance are extremely difficult to deal with and can create loss of business and money, so a combined reinforcing solution was the obvious choice. And at only 280mm thick with steel fibres and top mesh, to carry 5 high stacked containers and 11 tonne axle load forklifts, it was easily the most economical solution too.

Silk Logistics Container Park – Yennora NSW

4,500m2 of heavy duty container pavement in Yennora NSW was required to be constructed in sections whilst the existing facility was still in operation. A combined reinforcing solution allowed for the different sections and shapes to be prepared and constructed in quick time to minimise the interruption to those operations. With only 30kg/m3 of steel fibre and top reinforcing mesh required, this solution was able to easily handle the 4 high stacked containers.

Recycling Facility – Auckland NZ and MSC Bulk Materials Storage – Tauranga NZ

Recycling facilities may not have quite as heavy loads as some of the other slabs discussed in this paper, however they are a very harsh environment, and have a lot of impact on the surface. So when this 50,000m2 facility was being designed the best solution was to eliminate all of the joints and saw-cuts. This made it a far more durable slab, and allowed it to be tied into the external walls where required.

Similarly bulk materials storage facilities benefit from eliminating all of the joints and saw-cuts, and can have the walls designed and constructed as completely tied into the slabs, a requirement when being used to retain those materials.

Veolia Waste Transfer Station – Banksmeadow NSW

Both the internal and external slabs were going to be subjected to harsh conditions at this major Sydney waste management facility for Veolia, so both areas were designed using combined reinforcing to eliminate the requirement for joints and saw-cuts throughout. Forklift axle loads of 100 tonnes along with containers would be operating on the external pavements, whilst the very aggressive domestic waste with low PH would be processed inside the facility. Both have been in operation and performing great since 2016.

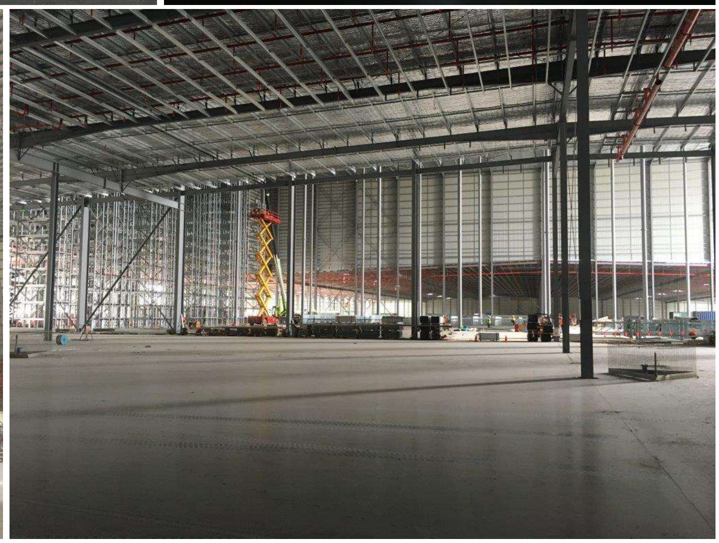
Northline Transport Distribution Centre – Kenwick WA

A number of different areas accommodating different loads, from single stacked containers and a 35 tonne combi-lift straddle handler, through to 2 high stacked containers and a 100 tonne axle load forklift, and others in between, meant that the pavement thickness could be adjusted for each area from, 160mm thick through to 290mm thick with steel fibre plus off-the-shelf reinforcing mesh. There was also typical fibre only external pavement and internal warehouse slabs on this project.

Ikea / Asahi Schweppes / Coca Cola – NSW & QLD

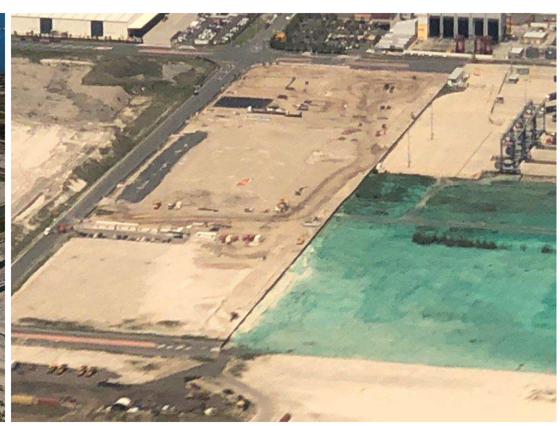
High-Bay warehouse facilities, often for automated racking systems, also apply very high racking post loads on the slab, therefore locking the slab in position, and restraining it, so the requirements are the same. Typical movement joints won't work, so a crack width design is again required.



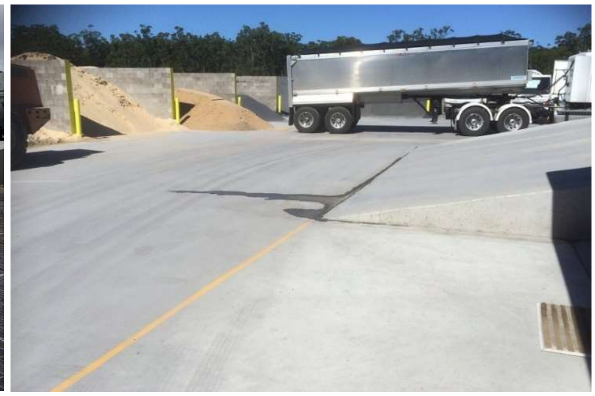
Silk Logistics – Port of Brisbane QLD

22,000m2 of external container park pavement, as well as 15,000m2 warehouse. After a similar, yet smaller, container hardstand was successfully constructed last year, is was clear that a similar combined reinforcing solution was going to provide the most suitable pavement to handle the 5 high stacked containers and massive forklift axle loads. This solution also has the added benefit of helping to reduce the construction program, being faster to complete than the alternatives.

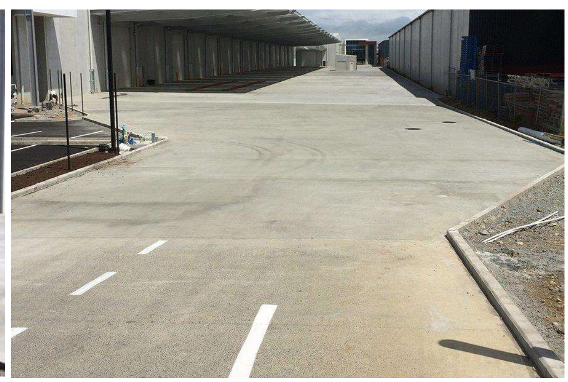
Premix Concrete Plant – Berkley Vale NSW

Huge numbers of truck movements in and out of a premix concrete plant can put considerable wear and stress on the concrete pavement. And the amount of water ever present in these facilities can also reap havoc on joints. When the inclusion of multiple spoon drains as well as the requirement for falls in the surface add significant restraint on the pavement, the best way to cope with it all at the same time is to move to a fully restrained combined reinforced concrete option.



Fonterra Container Pavement – Westney, Auckland NZ

50,000m2 of external container pavement constructed as completely seamless with steel fibres and top mesh, to eliminate joints and saw-cuts and cope with the very long and narrow shape of the facility.



Mainfreight Container Pavement – Prestons NSW

The original conventional design for the 5,000m2 of external container pavement on the new Mainfreight facility in Prestons NSW was 250mm thick. By changing the design to a completely seamless combined reinforcing solution, it was able to be reduced to 180mm thick with 30kg/m3 of steel fibre and off-the-shelf top reinforcing mesh. This reduced thickness also matched the existing driveway, minimising excavation works and saving significant time and money on the project. This facility also included 30,000m2 of SFRC internal warehouse slabs.

Conclusion

Designing Container Parks and Heavy Duty Pavements using a combination of steel fibre reinforced concrete and conventional reinforcing steel provides the designer with far more flexibility removing the usual constraints, such as restraint, shape and size. Now a very high quality pavement can be designed and constructed to accommodate the huge loads that are applied in these types of facilities, whilst at the same time providing a far more durable asset that will require no, or minimal, maintenance throughout it's life. Whilst this solution is also very suitable and attractive in many other applications also, it is clear from the number of these types of facilities that are in operation and that continue to be constructed that it is perfect for Container Parks and Other Heavy Duty Pavements.

References

1. Australian Standards AS3600:2018 - Concrete Structures - Published by Standards Australia.
2. Austroads, Guide to the Pavement Technology Part 2: Pavement Structural Design.
3. Brite-Euram, BRPR-CT98-8013: Test and Design Methods for Steel Fibre Reinforced Concrete.
4. Understanding Steel Fibre Reinforced Concrete: Dramix – Author: Gerhard Vitt – Published by NV Bekaert SA.
5. The Structural Design of Heavy Duty Pavements for Ports and Other Industries – Published by British Ports Association.