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INVESTIGATION INTO THE REASONS BEHIND PANEL FAILURE IN THE DURBAN CONTAINER TERMINAL – PIER 2

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ABSTRACT
The Durban Container Terminal (DCT) is currently the biggest and busiest container terminal in Africa and handles about 2.7-million TEUs a year. DCT handles approx. 70% of South Africa's containers and generates 60% of South Africa's revenue (Port of Durban, 2014).

Concrete panel failure in the vicinity of the stack area can pose serious safety risks for Straddle Carrier (SC) drivers. An investigation into the reasons behind panel failure in Pier 2 at DCT was carried out during a pavement rehabilitation project and is presented in this paper. The results were analyzed and conclusions, as well as recommendations were made.

KEYWORDS:.

INTRODUCTION
The existing pavement throughout the terminal is in-situ, unreinforced concrete slab, generally 375mm deep. Much of the paving has been in use for 35 years and is at or near the end of its design life. The paving is drained by continuous slot drains, generally running the length of the terminal. Pavement rehabilitation is ongoing at DCT. The most recent pavement rehabilitation project entailed 585 panels that needed to be demolished, 68654m of joint sealing, 695 partial repairs and 3850m of slot drain cleaning. Data was collected from this project as well as previous projects to identify various causes behind panel failure.

OBJECTIVES OF THE STUDY
The main purpose of this study was:
1) To identify the reasons behind panel failure at DCT.
2) To make recommendations on repair methods based on the findings.

Study limitations
This study is based on data collected during various pavement rehabilitation projects within the vicinity of berth 108-205. Figure 1 shows a detailed layout of the area covered by this study.

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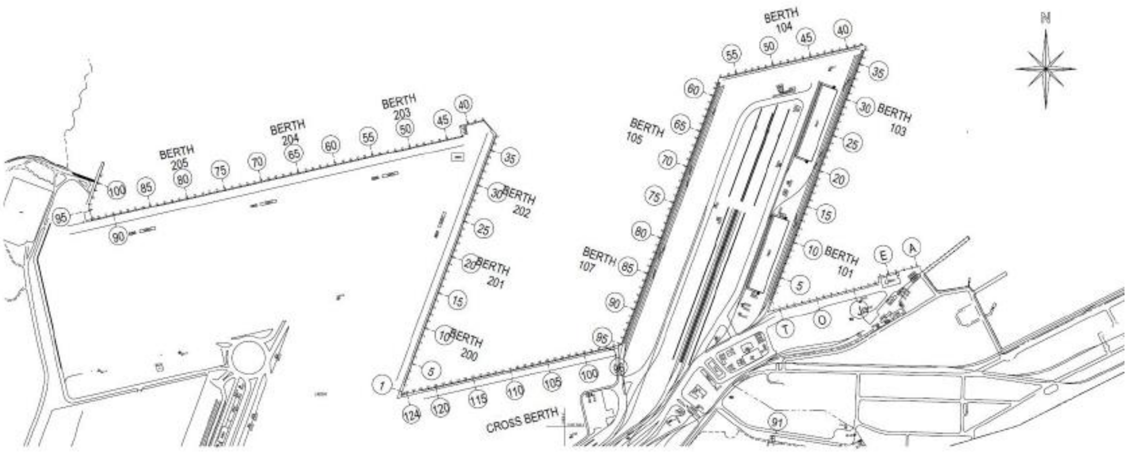

Figure 1: Detailed layout of DCT

REASONS BEHIND PANEL FAILURE AT DCT

Improper placement of dowel and tie bars

Dowel bars are commonly made of round, smooth, epoxy coated steel bars. Tie bars are made of deformed epoxy coated steel. The purpose of dowel bars is to transfer the load from one slab to another and reducing joint faulting and corner cracking (Figure 2). The purpose of tie-bars is to prevent lane separation and differential deflections (Figure 3). Tie-bars also reduce transverse cracking. (Khazanovich 2011: 4-5)

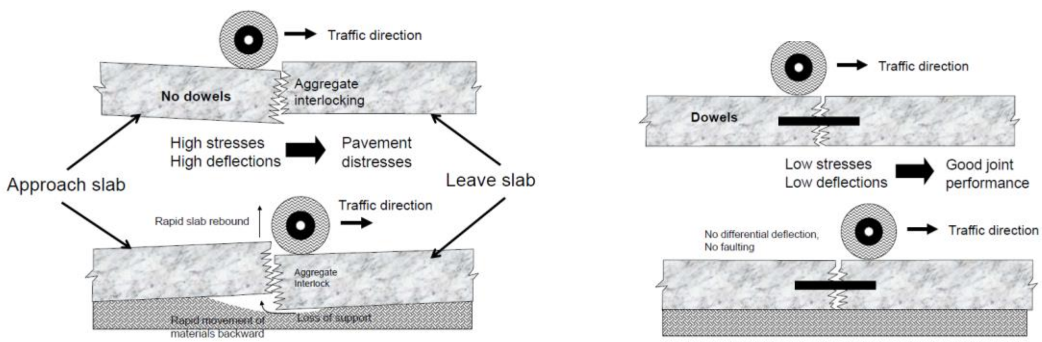

Figure 2: Purpose of dowel bars

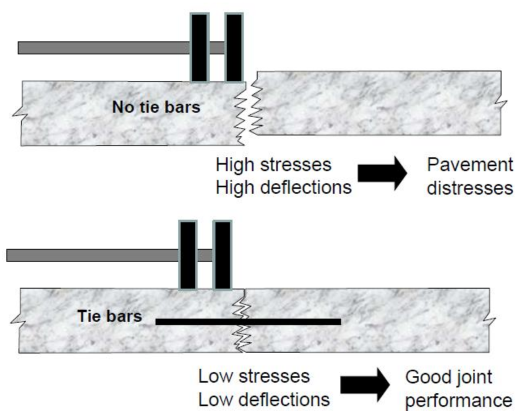

Figure 3: Purpose of tie bars

Placing bars at incorrect depths

Figure 4: Bars placed at incorrect depths resulted in spalling (Khazanovich 2011: 45-46)

Dowel bars provide load transfer across joints which reduce stresses and deflections thereby reducing faulting at joints and slab cracking. However to ensure proper functioning of the dowels, proper placement is critical. The above figure (figure 4) displays an example of a dowel bar that was placed incorrectly, which resulted in spalling, due to insufficient cover.

Clashing of bars

Clashing of the bars will result in spalling and cracking. The tie bar pointed out in Figure 5 will not be effective in preventing lane separation and deflections due to clashing of the bars. This will ultimately lead to panel failure.

Figure 5: Clashing of bars (Khazanovich 2011: 49)

Recommendation

- Dowel and tie bars should be placed mid-depth of the slab.
- When installing dowel and tie bars loose concrete should be removed from the concrete face.
- A bond breaking compound should be applied to the face of the concrete and on one half of the dowel bar (the half that does not have epoxy applied).
- Dowel bars are generally placed transversely and tie bars longitudinally.
- When placing dowel and tie bars ensure that there is sufficient spacing between the bars to avoid clashing.
- To avoid poor joint performance and inadequate load transfer, dowel and tie bars should be placed at 90º to the face of the concrete.

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Fly ash used as infill material

Fly ash is inconsistent in terms of thickness and quality and is therefore not graded or classified as G6, 7, 8 or 9. Sometimes you do get decent material but it is very fine and cannot be compacted (similar to cake flour). Concrete pavements rely on the layers below for support, so imagine a sheet of glass on mattress vs it being on a table. The concrete can withstand a certain amount of flexure as it is unreinforced, but as soon as we have "soft spots" then we get differential settlements which results in premature failure. There were serious panel failures in the areas that contained fly ash material in Pier 2.

Recommendation

Firstly trial pits were excavated (figure 6) and samples were taken to the laboratory to test and confirm that the contaminated material was actually fly ash. Thereafter, all the fly ash material was cut and spoiled (figure 7) and replaced with G5 and G2 up to the underside of the slab. The depth of the fly ash material went as far as 1 meter deep (figure 8).

Figure 6: trial pits

Figure 7: contaminated material

Figure 8: flyash approx 1 meter deep

Damaged stormwater pipes

Damaged stormwater pipes were one of the common problems that contributed towards panel failure at DCT. Due to the loss of sand through various cracks on the pipe (Figure 9) , the layer works above the stormwater pipe destabilized which eventually resulted in panel failure. Figure 10 and 11 depicts the collar of a stormwater pipe being repaired after it was discovered to be broken.

Figure 9: damaged stormwater pipe

Recommendation

Due to the flooding of excavations because of high tides (Figure 10), a quick and effective solution had to be implemented when excavating down to the damaged stormwater pipe. As a quick solution, it is recommended that bidim be wrapped around the vicinity of the collar and secured with binding wire (Figure 11).

Figure 10: working against the tide

Figure 11: wrapping bidim around the pipe

Slot drains not maintained

Slot drain cleaning plays a pivotal role in ensuring concrete panels maintain the life expectancy period and must be practiced on an ongoing basis. When slot drains are blocked (figure 12), water will pond on the surface of the concrete and will eventually seep in joints where the sealing has been omitted or has become old and needs to be replaced. Thereafter the water will begin to undermine the slab by weakening the layerworks underneath which will eventually lead to a panel failure.

Figure 12: blocked slot drain

Recommendation

- After a slot drain is cleaned a team should return to that slot drain at least every 3 months due to the fact that oil and grease will always block the drain.
- Slot drain cleaning should be practiced on an ongoing basis and a full time drain cleaning team should be employed to carry out this task.
- The correct procedure to clean a slot drain is to firstly remove debris using a tool called a spoon (Fig13 & 14) and thereafter perform hydro-jet cleaning to the drain.

Figure 13: spooning

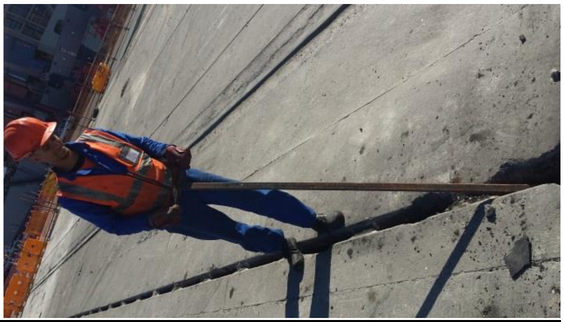

Figure 14: spooning

Unsuitable backfill material

It was noticed that unfitting backfill material (figure 15) was used in some areas in Pier 2. This resulted in hard and soft spots (figure 16) being formed in the vicinity in which there were vast amounts of panel failure. Serious panel failure resulted due to the fact that this material lacked compaction and subgrade uniformity.

Figure 15: Rubble used as backfill

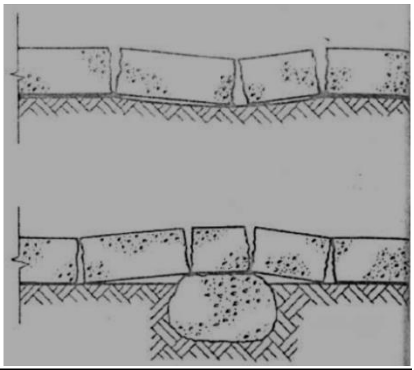

Figure 16: Hard and soft spots

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Recommendation

The unsuitable material should be removed and replaced with imported G10 and thereafter be completed with 150mm of G5 and G2 up to the underside of the slab. After compaction of each of these layers density tests should be carried out progressively. Density tests should be done at least every 300mm on the G10 depending on the depth of the backfill.

Joints not maintained

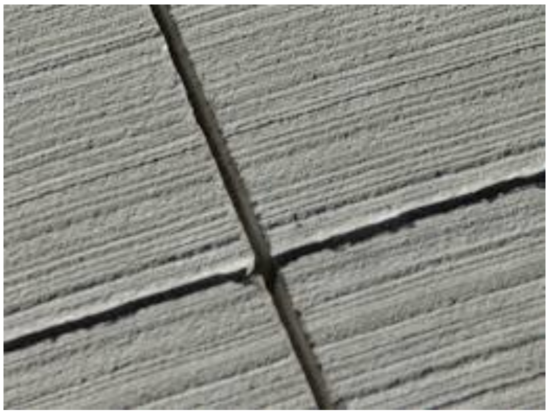

Figure 17: absence of joint sealing

One of the causes of panel failure is the lack of maintenance of joints. When water ponds on panels due to insufficient surface runoff or slot drain blockages, it eventually seeps through joints if the joint sealing is worn, omitted or sealed using improper techniques. Eventually the water will then undermine the slab by weakening the subgrade and will ultimately lead to panel failure.

Joint sealing prevents incompressible materials from getting lodged in the joint space, which can cause spalls. Sealant materials must be able to withstand repeated expansion and compression as the pavement slabs expand and contract with temperature and moisture changes. There are three different categories of sealants: hot-poured liquid sealants, coldpoured silicone sealants, and preformed compression sealers.

Recommendation

- Joints should be inspected on a regular basis and sealed when required.
- After sealing it is recommended that a pull out test be carried out.

Failure along quay wall

There was an increase in panel failure along the quay wall. An investigation was carried out and it was discovered that the existing marine sand was seeping through the joint of the quay wall during high tides. Failure of the road and concrete panels resulted from the destabilization of the layerworks, which occurred over a protracted period (Figure 18)

Figure 18: destabilization of the layerworks

Recommendation

Fix bidim on the joint as a quick yet effective solution due to the flooding of excavations because of high tides. Water pumps had to be used whilst repairing the quay wall to reduce the accumulation of water during high tides (Figure 19)

Figure 19: water pumps used

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