Macro-Synthetic Fiber Reinforced Concrete – Experience with Port Pavements Application

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INTRODUCTION

Ashdod Port successfully tries a use of Macro-Synthetic Fiber Reinforced Concrete (MSFRC) pavements since 2007. The pavements in ports are subjected to rather rough (sometimes brutal) handling, due to unavoidable impacts.

Concrete pavements are not new ones at cargo terminals. Some manuals and standards recommend a use of steel fiber reinforced concrete pavements, especially at container stacking yards.[1, 2]

It is known that fiber reinforcement does not prevent concrete cracking, as fiber gets involved at a post-peak stage. That makes fiber exposed to an environment, which is chlorides-rich in marine conditions. That is the reason why for experiments in the port were chosen synthetic macro fibers, mostly polypropylene ones, which correspond to the most modern recommendations for concrete pavements[3]. The following text presents some results of these experiments with different types of fibers, fiber dosage, concrete mixes, types of concrete floor' joints, etc.

FIRST EXPIERENCE

In 2007 the trial area of about 2,500 sq. m was cast on Quay #5 (Bulk cargo quay), for which a pavement thickness of 33 cm was chosen as for non-reinforced concrete. According to our previous experience[4], the "Enduro 600" fiber has been chosen with a fiber dosage 5 kg/cub. m (~0.5% of the volume). The concrete specification's requirements were as follows:

- The concrete should include no more than 280 kg/cub.m of CEM II to limit a hydration heat.
- The aggregate should be type A by Israeli Standard 3 (dolomite by local experience)
- The concrete should be suitable for pumping
- The flexural strength of concrete should be 4 MPa at least.

The fibers were added to concrete mixer on site.

The first casts were controlled by the concrete plant's technologist. A helicopter troweling was applied.

Two weeks after completion of the work it was found that the crane operators prefer to execute bulk operations without steel "bath", which should prevent the pavement from an impact caused by a free fall of a grab. Such impact resulted in appearance of local damages up to 15 mm deep. However, no concrete cracks were observed.

The most considerable problem of this pavement was low friction at the area in rain periods due to bulk material spread together with water on the pavement – it made the driving dangerous there. So the scrubbing of surface had to be executed. In the spec of all next projects a rough helicopter troweling together with rough brushing were required.

Another problem was durability of the floor joints, when the pavement' rough cleaning from bulk products was executing by a bulldozer to collect the maximum of spilled material. As a result of such cleaning a lot of elastomeric material of joints' fill was damaged and sometimes

detached. Hereinafter, a height of the sonomeric fill was increased and an angle cutting of joint areas was added.

NEXT PROJECTS

As far as the trial was in general successful, new projects with total area of about 36,000 m^2 have been executed. The concrete mix was changed to standard B-40 (equal to European C30 concrete), with reduced fiber dosage to 4.5 kg/m^3 only.

Different examples of fibers were tested to ensure the equality of MSFRC behavior. The following fibers were found as equal:

- "Enduro 600" (#1 in Figure 1)
- "Ferro" by Forta (#2 on Figure 1)
- "Mayco" by BASF (#3 on Figure 1)
- "Durus S200" by Adfil (#4 on Figure 1)
- "Durus 50" by Adfil (#5 on Figure 1)

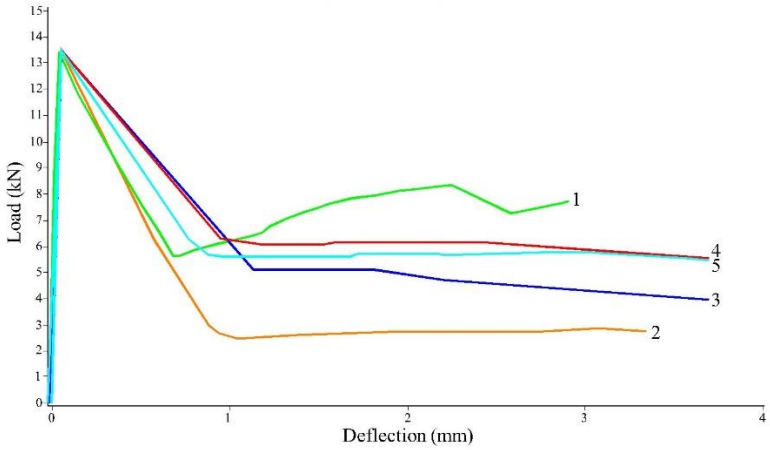

Figure 1. Flexural toughness test results by ASTM C 1018 (for comparison purposes)

Actually, only fibers 1 and 2 were used in described projects, as no difference in the pavement's behavior was found.

During first projects, the fibers were added to concrete mix on site by manufacturer's recommendation to prevent fibers balling. In the following projects, the mix was delivered from a concrete plant already with fiber. At that, no difference in the mix behavior was found.

The pavements were tested for different types of bulk and general cargo and found suitable even for the steel scrap handling – the most violent (for pavements) cargo type (Figure 2). The maximal found pavement damage for this cargo type is shown on Figure 3.

Figure 2. Steel scrub handling on the concrete pavement in Ashdod port

Figure 3. The depth of maximal pavement's damage after steel scrubs handling

JOINTS

The structural joints span was predetermined by the cast technology – along a quay, with strips of 5 m wide width. Two days after a cast, saw cut joints were executed in perpendicular to the quay line direction. The details of two types of joints are presented in Figures 4 and 5.

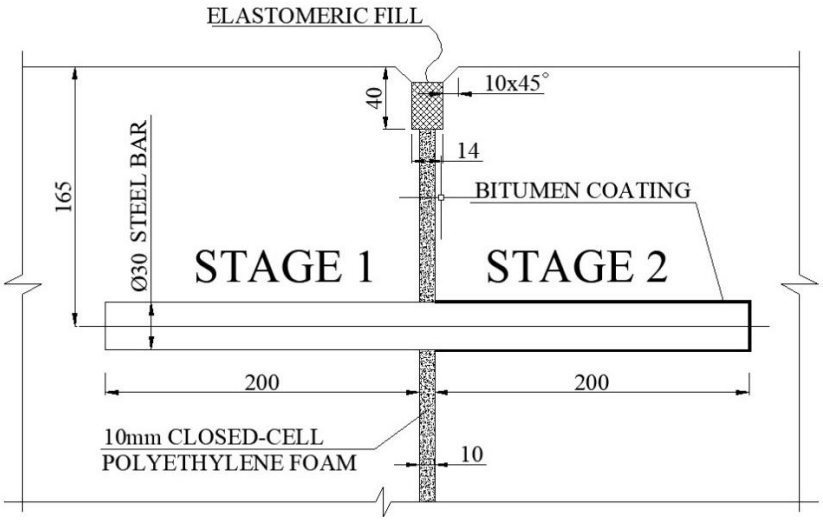

Figure 4. The structural joint detail

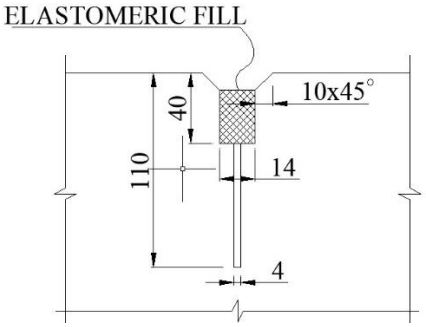

Figure 5. Saw cut joint detail

It is possible to say that mostly the joints performed their function, but sometimes the pavement cracked, even next to a joint – see Figure 6.

Figure 6. Cracks next to the saw cut joint

CONCLUSIONS:

1. MSFRC pavements are more suitable for operation area of wharves for bulk and general cargo, than other known types of port pavements.
2. It is possible to add fibers both in concrete plant and on site.
3. The joints fill in port MSFRC pavements should be deeper than in other types of concrete floors.
4. According to the port's experience, though it occurred impossible to prevent a cracking in MSFRC pavements, it did not interfere with the operation of the pavement. After 12 years of intense cargo operations, the pavements does not require any repair.

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