9th. International Conference on Concrete Block Paving. Buenos Aires, Argentina, 2009/10/18-21
Argentinean Concrete Block Association (AABH) - Argentinean Portland Cement Institute (ICPA)
Small Element Paving Technologists (SEPT)

CONCRETE BLOCK PAVEMENTS FOR CONTAINER STORAGE AREAS IN ARGENTINA

GRANADA, Juan, Engineer

General Director of Ports Infrastructure, Province of Chubut, ARGENTINA.

HERRERA, Claudio, Civil Engineer

Manager of Promotion and Technical Services - Commercial Management
Petroquímica Comodoro Rivadavia S. A..
Don Bosco, km 8, (9003) Comodoro Rivadavia, Chubut, ARGENTINA.
Tel./Fax.: + 54-297-4535189, cherrera@pcr.com.ar

Note: The following is the notation used in this paper: (.) for decimals,( ) for thousands.

Summary

This paper describes two container storage platforms, built with concrete block pavements (CBP) in two cities; Puerto Madryn and Comodoro Rivadavia, both in the province of Chubut in Argentina.

The objective of their construction was to provide both ports with the facilities for containers storage with normal and special loads, in order to be better prepared to receive new exports and imports. The first platform was built in 2005, with a surface of 14 500 m^2; the second was built in 2008, with 11 500 m^2.

The analysis of several alternatives for Puerto Madryn selected a concrete block pavement for its technical and economic advantages like the possibility to be built by local contractors with no specialized equipment and labor, and the evidence of a good behavior, endorsed by more than 6.5 million m^2 of concrete pavers, laid in ports and storage platforms around the world.

The project of Comodoro Rivadavia was directly designed with a concrete block pavement, with some changes that would improve their behavior. Those changes were made after the experience in Puerto Madryn and some doubts presented by the designers on the long-term behavior of the platform. It must be noted that the specifications for the bidding process of this platform, accepted the presentation of alternatives to the concrete block pavement.

1. CONTAINER STORAGE PLATFORM, ADMIRAL STORNI PIER, CITY OF PORT MADRYN, PROVINCE OF CHUBUT, ARGENTINA

1.1 Description

It is a container storing platform, with a surface close to 14 500 m^2, paved with concrete blocks. It is used for different goods with source or destination in the port of the city of Puerto Madryn, in the province of Chubut, Argentina. The containers for perishable goods need to be permanently refrigerated, so they require electricity sources during storage. This is the reason for the provision of 120 energy boards to feed more than 2 000 containers.

The Port Administration faced this project in order to provide the Admiral Storni Pier with the adequate facilities to capture a portion of the production of the Río Negro Valley, currently

exported to Europe through Puerto San Antonio, located to the North. This project will allow the incorporation of a transoceanic line, to reach those markets, something impossible to do at that time.

1.2 Concrete block pavement

A concrete block pavement with 80 mm thick "Uni-stone" pavers, in herringbone pattern, was built for the platform. The pavers were Type I units, according IRAM 11656 Standard, i.e. those for public roads, airports, ports, load storage platforms, etc. To be Type I mean to have an average compressive strength of more than 45 MPa and no individual value of 40 MPa for each specimen.

The laying of the blocks followed the recommendations of the IRAM 11657 Standard "Concrete Blocks for Pavements. Requirements for laying and recommendations for its basic structure" and the Particular Technical Standards.

The concrete block pavement was designed to be heavily trafficked by semi-trailer trucks and 71.5 t (self weight) "front-lift" container handling equipment. In addition, it is expected to store containers stacked in height, with the consequent increase in loads in the points of support.

The following is the design data for the concrete block pavement:

- Front lift container handling equipment, type Reach-Stacker B98M, with the following characteristics:
  - Own weight = 71.5 t.
  - Wheelbase = 4.80 m.
  - Distance between the centre of gravity of the container and the front axle = 2.56 m.
  - Distance between centers of gravity (for the container and the equipment) = 5.31 m.
  - Number of tires in the front axle = Four (4).
- Critical weight of the mixture of 40 ft/20 ft containers = 21 t.
- Two alternatives design lives = 250 000 and 1 000 000 axels.
- Two dynamic load factors = Braking and irregular surface, acting together and separately.
- Value of support (CBR) of the subgrade = 10%.

The designer considered granular and soil-cement as base materials. The granular alternative was chosen for being the most feasible to be built, with equivalent support value. Therefore, the structure was made of pavers on the bedding sand, followed by granular layers of base and subbase, with a gradually increasing carrying capacity from the subgrade up to the paver layer, with a total thickness of 0.8 m (see Figures 1 and 2 and Table 1).

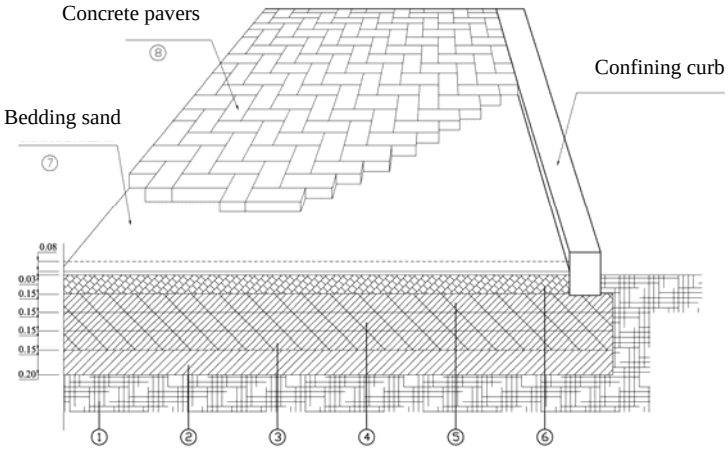

Figure 1. Outline of the structural package [structure].

Table 1. References in Figure 1.

1 Subrasante.	Natural ground.
2 Granular subbase.	Degree of relative compaction (GCR) greater than or equal 93 % of the dry density obtained with the material in the modified Proctor test T 180; thickness = 200 mm.
3 Granular base 1.	Degree of relative compaction (GCR) greater than or equal 95 % of the density dry obtained with the material in the modified Proctor test T 180; first layer, 150 mm thick.
4 Granular base 2.	Degree of relative compaction (GCR) greater than or equal 95 % of the density dry obtained with the material in the modified Proctor test T 180; second layer, 150 mm thick.
5 Granular base 3.	Degree of relative compaction (GCR) greater than or equal 95 % of the density dry obtained with the material in the modified Proctor test T 180; third layer, 150 mm thick.
6 Granular base 4.	Degree of relative compaction (GCR) greater than or equal 98 % of the density dry obtained with the material in the modified Proctor test T 180; fourth layer, 150 mm thick.
(Soil-cement base).	Seven (7) days compressive strength > 2 MPa, 150 mm thick.
7 Bedding sand.	The thickness of the bedding sand (coarse sand) shall be even and have a thickness between 30 and 50 mm thickness, after vibration and compaction of the surface layer.
8 Concrete pavers.	According with standard IRAM 11656, type "Uni-stone". PS8, grey color, de Petroquímica Comodoro Rivadavia or similar.

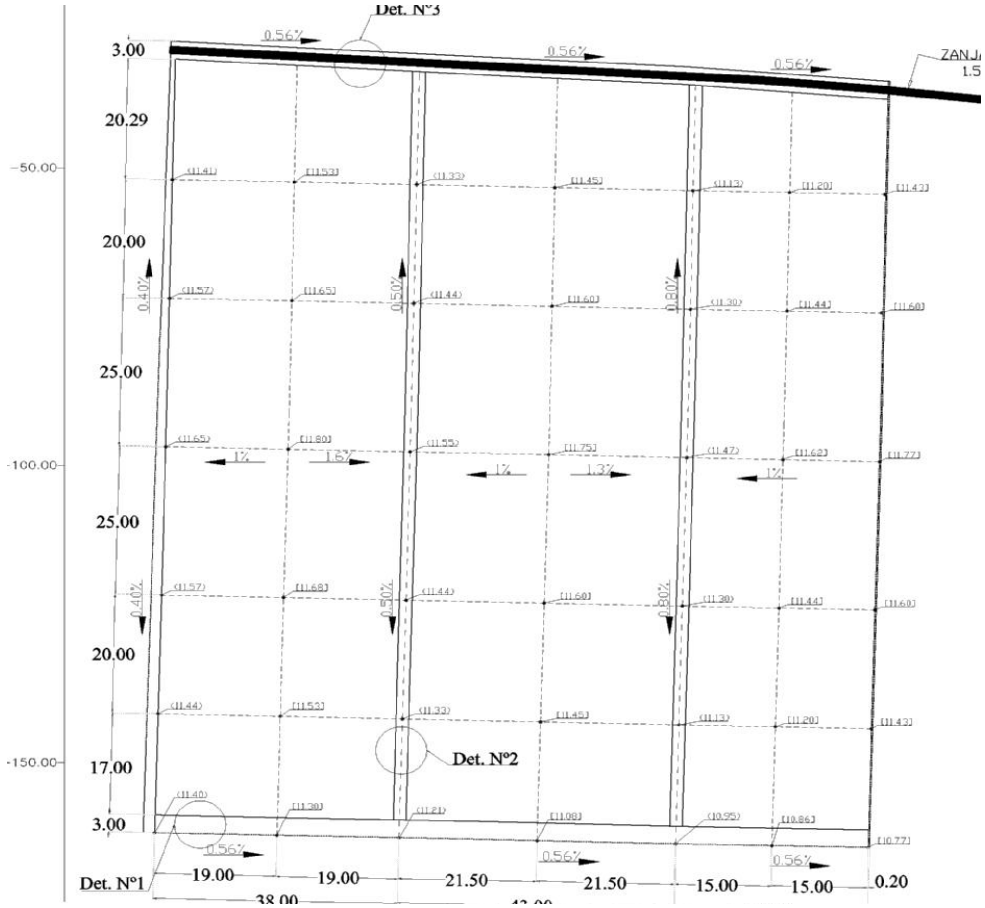

Figure 2. Layout of concrete gutters and the runoff direction.

The design included unreinforced concrete gutters, strategically located in order to collect the rainwater runoff. The location was selected such that the containers interact as little as possible with the runoff, avoiding operational problems and the generation of counterproductive dynamic actions for the pavement's structure (see Figures 3 and 4).

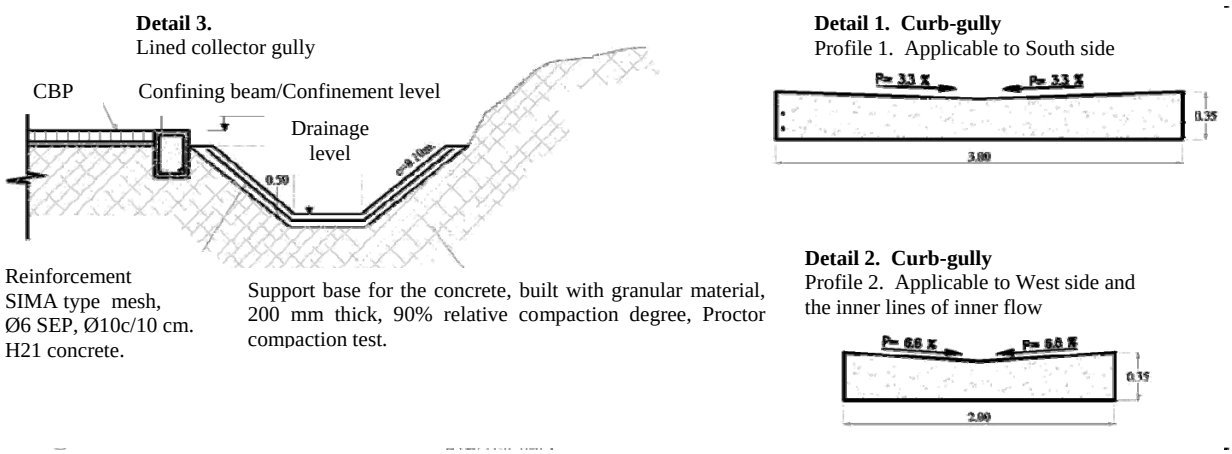

Figure 3. Details of concrete gutters according to the references of Figure 3.



Figure 4. General view of the concrete gutters for the surface water runoff.

The concrete block pavement alternative was selected among concrete, asphalt, concrete blocks, for its technical and economic advantages. Concrete block pavements allow to be built by local contractors with no need for special equipment or specialized labor. In addition, there is evidence of their good behavior, endorsed by more than 6.5 million m^2 of concrete pavers used in ports and container platforms in various parts of the world, to the date of this project.

The selected structure can be built with traditional techniques and equipment well known and widely used by local contractors. The Contracting Agency defined this purpose from the beginning of the project (see Figures 5 to 7).



Figure 5. Constructive stage of the concrete block pavement (Detail 2 of Figure 4).



Figure 6. Construction of the gutter (Detail 3 of Figure 4).



Figure 7. Operating finished pavement.

2. CONTAINER STORAGE PLATFORM FOR PORT OF COMMODORE RIVADAVIA, CITY OF COMMODORE RIVADAVIA, PROVINCE OF CHUBUT, ARGENTINA

2.1 Description

It is a concrete block paved container storage platform, with a surface close to 11 500 m^2, to be used for general goods. Its maximum capacity, for three-high storage, is 240 containers.

Electricity boards were installed to allow the operation of refrigerated containers.

Although the Port of Comodoro Rivadavia had grown in previous years with the extension of the sea shelter, the construction of docks, the paving of access roads, and more, the available storage area was low. Hence the need for the construction of this platform, with possibilities for future expansion to surrounding areas (see Figure 8).

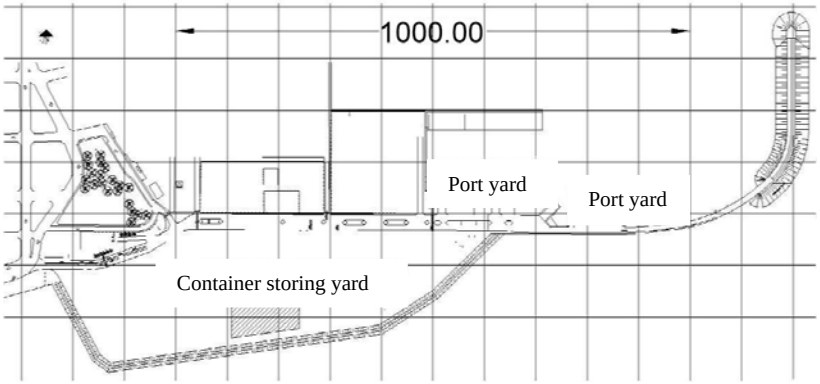

Figure 8. Location and layout.

2.2 Concrete block pavement

A concrete block pavement with 80 mm thick "Uni-stone" pavers, in herringbone pattern, was built for the platform. The pavers were Type I units, according IRAM 11656 Standard, i.e. those for public roads, airports, ports, load storage platforms, etc. To be Type I mean to have an average compressive strength of more than 45 MPa and no individual value of 40 MPa for each specimen.

The laying of the blocks followed the recommendations of the IRAM 11657 Standard "Concrete Blocks for Pavements. Requirements for laying and recommendations for its basic structure" and the Particular Technical Standards.

The designer did not analyze any alternatives in this project because an extra advantage was added to those listed for a concrete block pavement in the Port of Madryn. It was the fact that this pavement had to be built on a "sea reclaimed" zone, filled with material from land cleaning, demolitions and other wastes for several years, the subgrade compaction was very uneven (see Figure 9).

Therefore, it was preferred not to use rigid pavements for the possibility of differential settlements that would make the slabs to lose support and to get broken by the traffic loads.

The use of asphalt pavements was not considered either, since a significant deformation can be generated within them, under big wheel loads and low traffic speed, in addition to the deformations caused by the frequent breaking and sharp turns of the container carrying equipment.



Figure 9. View the unfinished fill near the container platform.

A concrete block pavement has a flexible behavior. It is made of small elements that "accompany" the deformations without collapsing. In the case of eventual breakage of the pavers and/or important differential settlements, it is quick and easy to repair, with no interruption of the port operations. However, the bidding conditions accepted the presentation of pavement alternatives. The design followed the same considerations made for Puerto Madryn, as described en paragraph 1.2.

The designers analyzed some alternatives for the base; granular and cemented materials with equivalent support values. The most feasible type was chosen from the point of view of its construction. The final structure has a concrete block surface on a sand layer. They are built on a 150 mm soil-cement base, and four (4) granular base layers and one granular subbase layer (0.8 m in total), with a carrying capacity gradually increasing from the subgrade to the top, giving a total structure of 0.95 m (see Figure 10 and Table 2).

An asphaltic emulsion primer (Type EM1) was applied over the subgrade, to avoid possible leakage of seawater in case of a full sea.

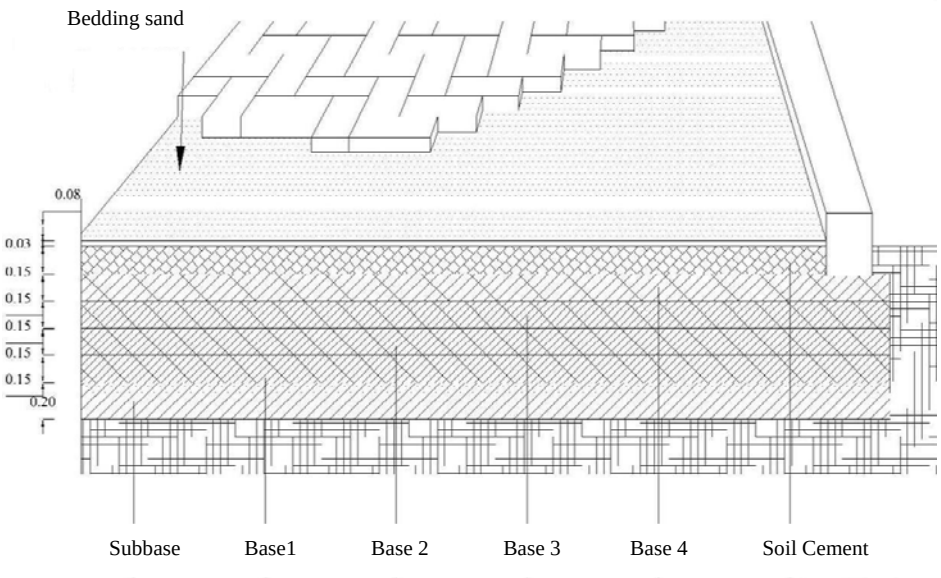

Figure 10. Structure of the pavement.

The storage platform has four (4) sectors defined by three concrete gutters or the evacuation of the surface water. The areas between the gutters have 1% slopes toward “two sides”. This will allow a rapid removal of water from the concrete block surface (see Figure 11).



Figure 11. Partial view of a concrete gutter.

Table 2. References in Figure 10.

Subgrade	Natural ground.
Granular subbase.	Degree of relative compaction (GCR) greater than or equal 93 % of the density dry obtained with the material in the modified Proctor test T 180; thickness = 200 mm.
Granular base 1.	Degree of relative compaction (GCR) greater than or equal 95 % of the density dry obtained with the material in the modified Proctor test T 180; first layer, 150 mm thick.
Granular base 2.	Degree of relative compaction (GCR) greater than or equal 95 % of the density dry obtained with the material in the modified Proctor test T 180; second layer, 150 mm thick.
Granular base 3.	Degree of relative compaction (GCR) greater than or equal 95 % of the density dry obtained with the material in the modified Proctor test T 180; third layer, 150 mm thick.
Granular base 4.	Degree of relative compaction (GCR) greater than or equal 98 % of the density dry obtained with the material in the modified Proctor test T 180; fourth layer, 150 mm thick.
(Soil-cement base).	Seven (7) days compressive strength > 2 MPa, 150 mm thick.
Bedding sand.	The thickness of the bedding sand (coarse sand) shall be even and have a thickness between 30 and 50 mm thickness, after vibration and compaction of the surface layer.
Concrete pavers.	According with standard IRAM 11656, type "Uni-stone". PS8, grey color, de Petroquímica Comodoro Rivadavia or similar.

Due to the characteristics of the "feet" of the containers (small corner blocks protruding 12.5 mm that transmit 1/4 of the total load) and that often during the handling operations, the containers are not gently placed on the pavement but they "fall" from some centimeters, the containers make a great stress and impact on the pavers and can break them.

Even though the characteristics of the concrete block pavement make it easily to repair, some already described facts made the designers to "strengthen" the standing areas with special precast beams (inverted "Ts"), finished "in-situ" with a layer of metal-fiber reinforced concrete (see Figures

12 and 13). The soil-cement was built with the on-site mixing method, using a motograder for the distribution of the bagged cement, to get the selected dosage, while generating the slopes.



Figure 12. Precast parts for the support of the "legs" of the containers, before the in-situ casting of the compression layer with metal fiber reinforcement.



Figure 13. Precast parts for the support of the "feet" of the containers, after the in-situ casting of the compression layer with metal fiber reinforcement.

In order to achieve a proper and uniform compaction, the soil-cement layer was built in one lift, and it was excavated where it was necessary for the construction of gutters and chambers. A 200 g/m^2 geotextile was placed between the soil-cement layer and the bedding sand.

The laying of pavers was made by a gang of 6/7 workers, achieving an average yields of 150 m^2/day per gang (21.5 to 25.0 m^2/worker) (see Figures 14 and 15).



Figure 14. Laying of pavers.



Figure 15. Overview of the finished pavement.