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Proven tunnel forms at works in the Acre – Karmiel Railway

B. Candeloro[(1)], M. Galimberti[(1)]

[(1)]*CIFA SpA – Zoomlion Heavy Industries, Senago, Italy*

ABSTRACT: At the beginning of 2012, CIFA signed a contract for the supply of 4 sets of formwork for the lining of the Gilon Tunnel which is constituted by two single track parallel tunnels, each one 4,7 km long, which include also 18 by-pass and escape tunnels. The need to meet a close deadline, the imposition of a restricted budget and the important length of the tunnels, imposed to find a balanced solution between costs saving and speed, by exploiting the skills of the constructor in digging and also its experience with proven and flexible lining methods. With regards to the lining phase, the choice of classical self-supporting formwork system is a key point to reach the targets making the most of the efficiency achievable with manpower and construction phases overlapping.

1 The Gilon Tunnel

The Acre -Karmiel (or Akko-Carmiel) railway project (2,8 billion ILS) is part of the Netivei Israel plan, a 27,3 billions ILS project to promote a more balanced distribution of the population, economic activities and social condition between the central region of the country and the North and South regions of Negev and Galilee.

The project is based on the commitment to make closer and accessible the various part of the country by creating a faster and more widespread transportation network.

The Netivei Israel plan will also include the HaEmek Railway project (4 billion ILS) which will connect the city of Haifa to the Beit Shean and other road infrastructure project.

The new Akko-Carmiel double track railway is going to connect the western city of Akko (Acre), located in the northern part of the Haifa Bay on the Mediterranean Sea coast, and the city of Carmiel, located at the same latitude in the upper region of Galilee.

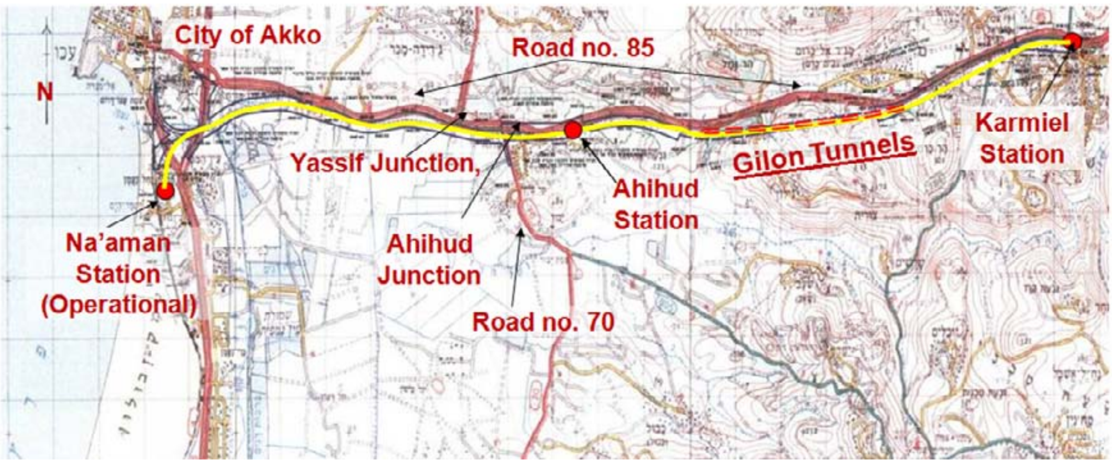

Figure 1. Project Plan

The new railway will join the existing coastal railway connecting the North to the South and will allow trains to run parallel to existing Highway 85.

Figure 2. Western Portal (illustration)

Figure 3. Eastern Portal: from project to construction

The project will includes also two new train stations, one in the middle of the route in proximity of Moshav Ahihud city (Ahihud Station) in the Western Galilee and the other at the entrance to Karmiel (Karmiel Station).

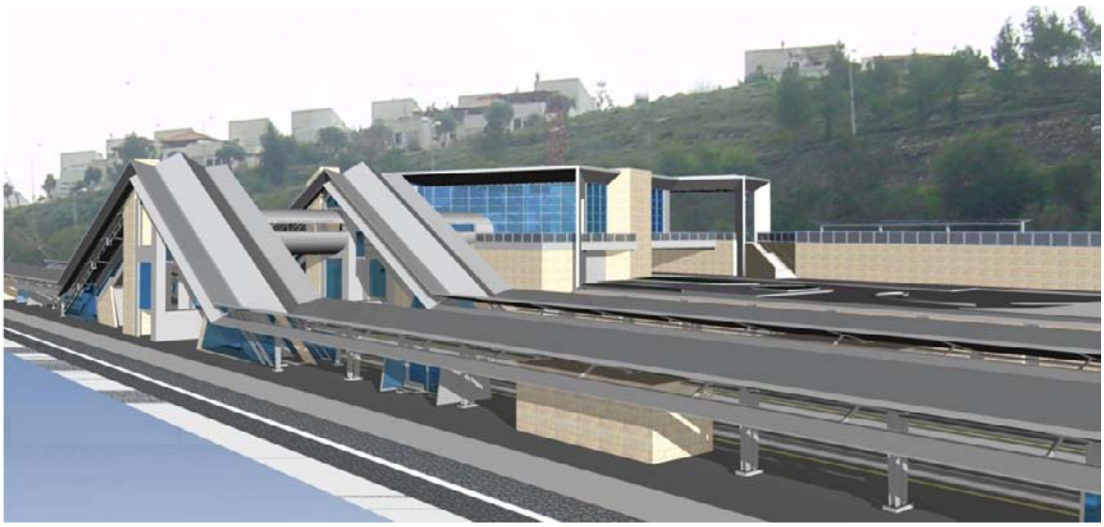

Figure 4. Karmiel Station (illustration)

The 23 km long double tracks project involves 7 contractors for different sections.

China Civil Engineering Construction Corp. (CCECC) and Danya Cebus Joint Venture (Gilon Tunnel Builders) won the tender to execute the third Segment, which is 6,75 km long and includes three parts, the West approach, Mining of Gilon Tunnels and the East approach.

Figure 5. Tunnel approach

The Gilon Tunnels includes two main tunnels, 4.625 km each, and 18 connecting tunnels between the two main tunnels, each of 17 m long and each one at a distance of 250 m from one another. The complete project means therefore a total length of 9,556 linear meters.

The total implementation period for the whole third segment is 39 months, which is scheduled to be completed within January 2015, meaning approx 27 calendar weeks for excavation, consolidation, reinforcing, lining and finalization. The opening for passengers of Akko Karmiel Railway would be March 2017.

At the beginning of the 2012, CIFA signed a contract with the JV between Danya Cebus and CCECC, for the supply of 4 sets of formworks for the construction of the tunnel.

2 The reason of a choice

The big challenge of engineers in the realization of any project is the reaching of the optimum with the cost to the minimum.

In a project performed under the Design&Build method, based on iterative optimizations aiming to cope progressively with the realization of the project itself, the constructor has the possibility to control the performances by adapting the construction process to the equipment disposal and vice versa.

In tunnelling construction, time is a variable whit a high level of imponderability and with a direct impact on the cost, and the controls of the time can be managed by choosing a robust and flexible production system, able to cope with the variability of the circumstances.

In this regard, flexible and reliable formwork system can represent a strategic choice which can make the difference to the reaching of the planned goals.

The Gilon Tunnel, is an example of tunnelling project based on the Design&Build method, in which the main constrain is exactly represented by time and budge respecting.

The considerable total length of the tunnel and the short time period availability imposed to organize the underground works as a continuous process in which the various phases were time overlapped and space shifted so that the excavation with drill&blast technique is carried out contemporary to lining.

With regards to the excavation process, the basic drilling cycle for drill & blast drifting and tunnelling was consisting of a sequence constituted by Surveying and setup – Drilling – Charging – Blasting – Ventilation – Scaling – Mucking – Spritzbeton Consolidation Lining – Bolting.

This process requires a proper organization of the job-site and the formwork system has to be properly integrated into the process permitting the free flow of excavation and mucking vehicles and permitting the ventilation pipes to pass along without interfere with the required vehicle free flow.

Considering the two parallel tunnels and the two excavation opposite directions, Gilon JV asked for a set of 4 equipments properly designed to follow the 4 excavation heads simultaneously.

3 The proposal

The typical section of the tunnel is horseshoe type, with pier walls extremely straight and high. The internal radius of the section is 3,93 m and the total height of pier walls is 4,9 m. Starting from the kicker, the total height of the internal vault is 8,83 m and the theoretical concrete thickness is 300 mm.

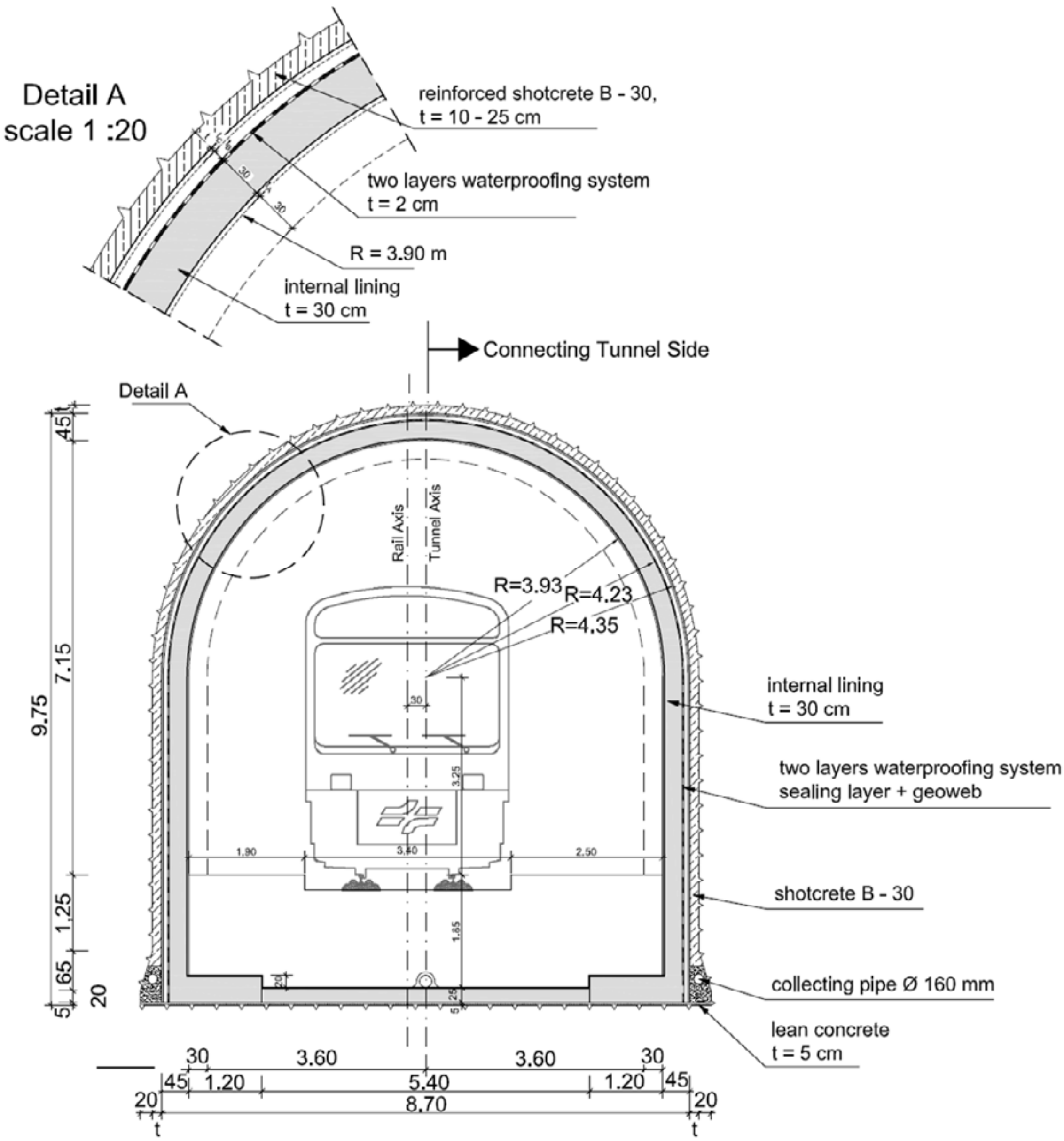

Figure 6. Standard Cross-Section

The study of the solution has been conducted assessing two main alternatives, having discharged since the beginning the solution of self-reacting system formworks, both because of the higher cost of the equipment concerned with the self-reacting structure, and because the inclination of the reacting struts would have been to be significantly vertical due to the high vertical stretched geometry of the section.

The first alternative would have been consequent to the particular shape of the section and, principally, from the very straight geometry and big height of the walls.

In this situation, it is usual to recur to a solution with crapauds, anchor bolts and tyloop inserts embedded into the concrete during the first phase casting, because, with straight walls, this solution is generally preferred making it easier dismantling the formwork after curing.

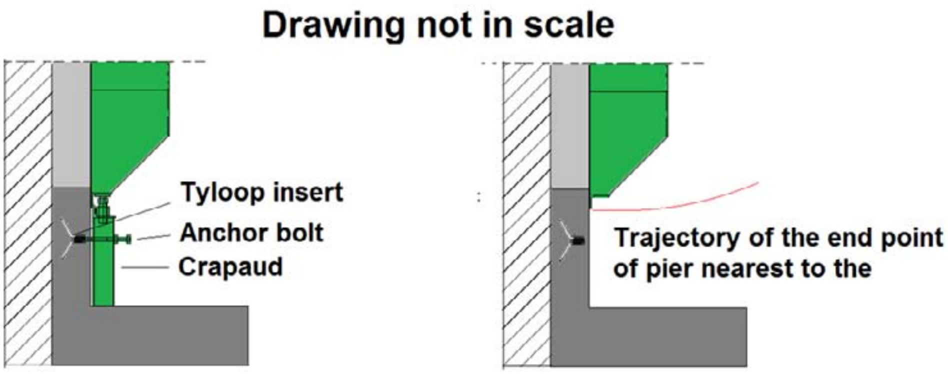

Figure 7. Crapauds-Tyloops system

Nonetheless, the small thickness of the concrete in combination with the load exerted by the fresh concrete pressure during casting, and the cost of the tyloop inserts, whose number would have been over 15.000 units, made it inappropriate this first alternative.

The second alternative was proceeding from the seeking of a system already experienced by the customer which was permitting the free flow of excavation and mucking vehicles. The system need moreover, to foresee a correct hosting of the ventilation pipes and to permit an economic and effective anchoring system.

The kicker base was sufficient large to accommodate both rails, in order to have the carrier legs out of the passage envelope, and head anchor pins which can be recovered. Such an anchorage system is to be used with self-supporting formwork system, but to take advantage of this simple and effective formwork solution it was necessary to solve the difficulties concerned with dismantling of the end-toe with straight walls geometries.

The solution carried out arose from designing a special end-toe with the supporting edge bevelled enough to reach the necessary escape angle.

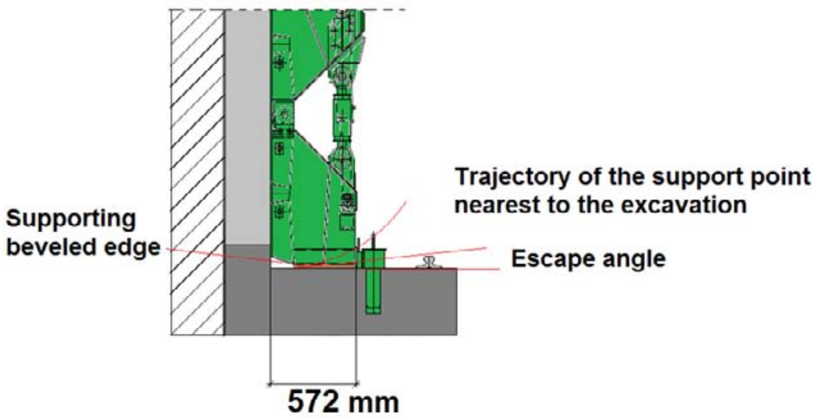

Figure 8. Special solution with bevelled edge contact point

This self-supporting solution was well appreciated by the Gilon JV both because of the wise cost investment and lower operating cost, and because it could exploit their skills previously experienced with similar equipment.

Once solved the anchoring system question, it was then designed the arrangement of the various element and the formwork lay-out.

Each equipment is provided with 12,0 m long forms and is composed by 5 rings of 2,4 m. Each steel form ring is composed of 2 vault forms, 2 piers and 2 end-toes, all with mantle thickness of 8 mm.

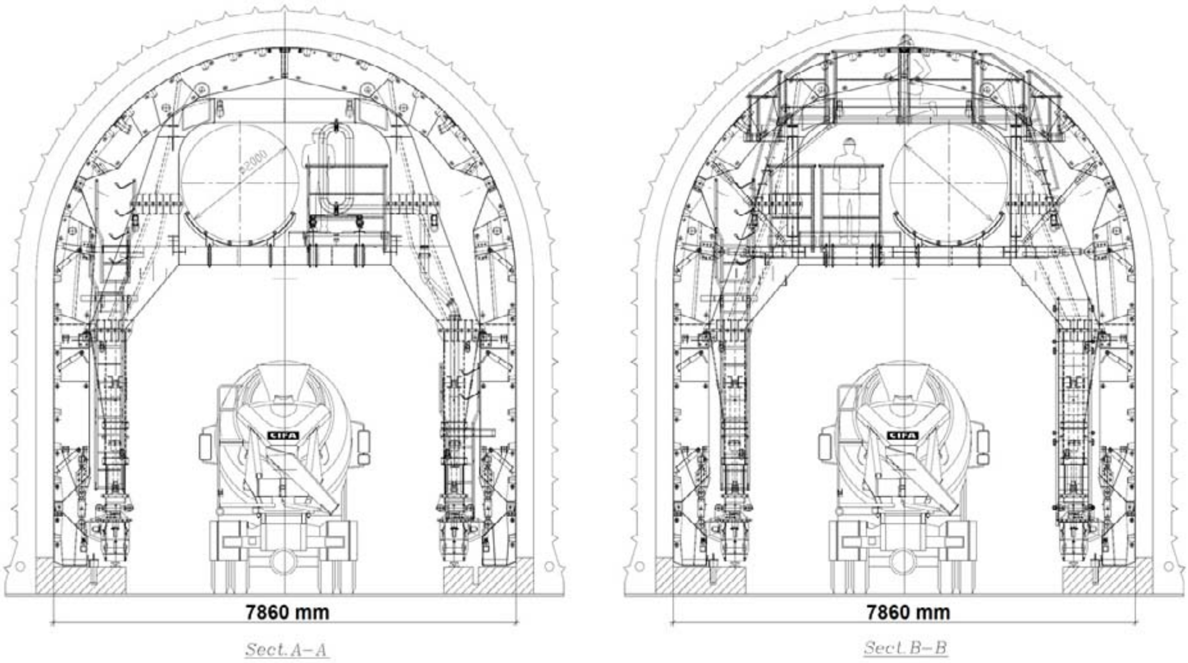

Figure 9. Cross section design

The connection between the vault, pier and end-toes elements is made with a series of hinges to permit the articulation for the dismantling phase; the locking of the hinged element in setting-up configuration, to maintain geometries and loads during the casting, is realized by means of adjustable screw props, and, at the base, the anchorage is granted by 18 recoverable head pins each side.

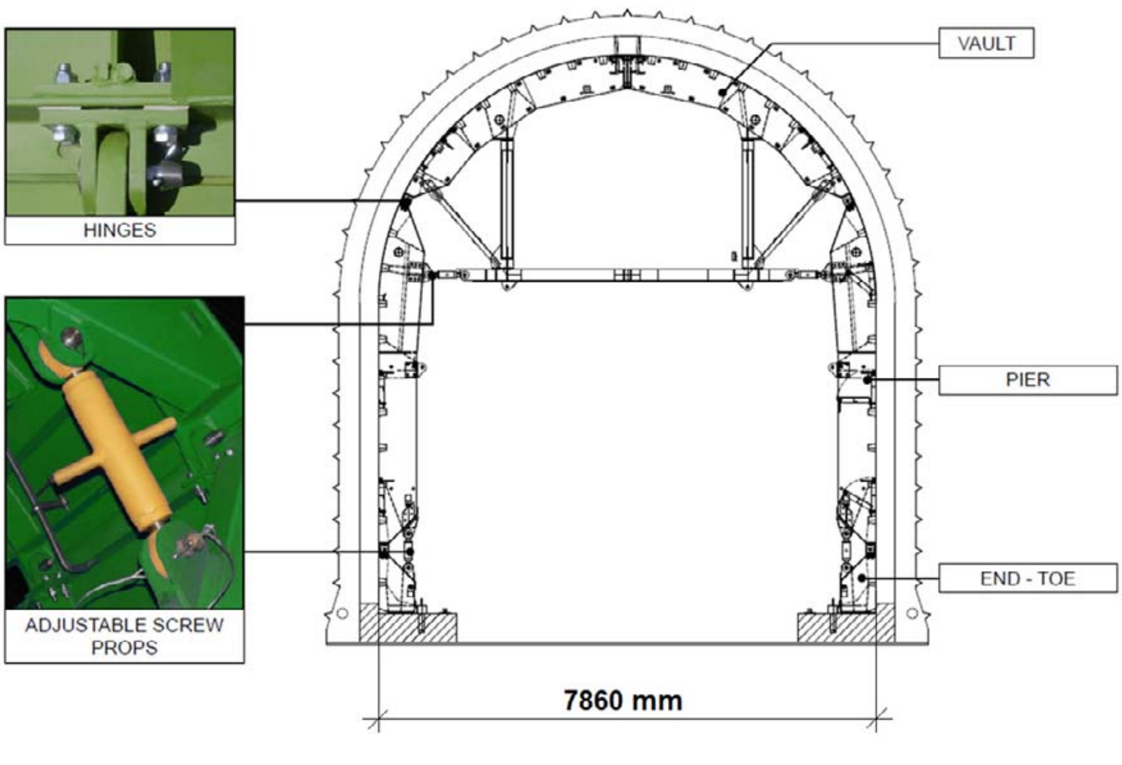

Figure 10. Elements articulation

The forms has been designed according to the main casting hypothesis of casting vertical speed of 1,5 m/h, a max. difference in height between the casting of one pier and the opposite one of 0,75 m which can allow to realize the casting in less than 8 hours.

The steel forms are also provided with hydraulic jacks for the movement of the elements, 20 doors for casting and inspection of concrete and 8 casting pipes applied on the mantle, 1 of which provided with pressure safety valve.

Each formwork is transported, set-up and dismantled by a dedicated carrier, which is consisting of two portals, with telescopic legs, which are connected two longitudinal trellis beams on which the steel form section is resting.

The formworks have the possibility to regulate their alignment with the axle of the tunnel by recurring to transversal adjustment, possible by means of 4 hydraulic jacks, each one connected to the upper and lower elements of the transversal adjustment device which is mounted between each male leg and each wheel unit.

The translation of the carrier is performed with 4 wheels units, 2 of which idle and 2 driving by means of chain transmission and hydraulic motors.

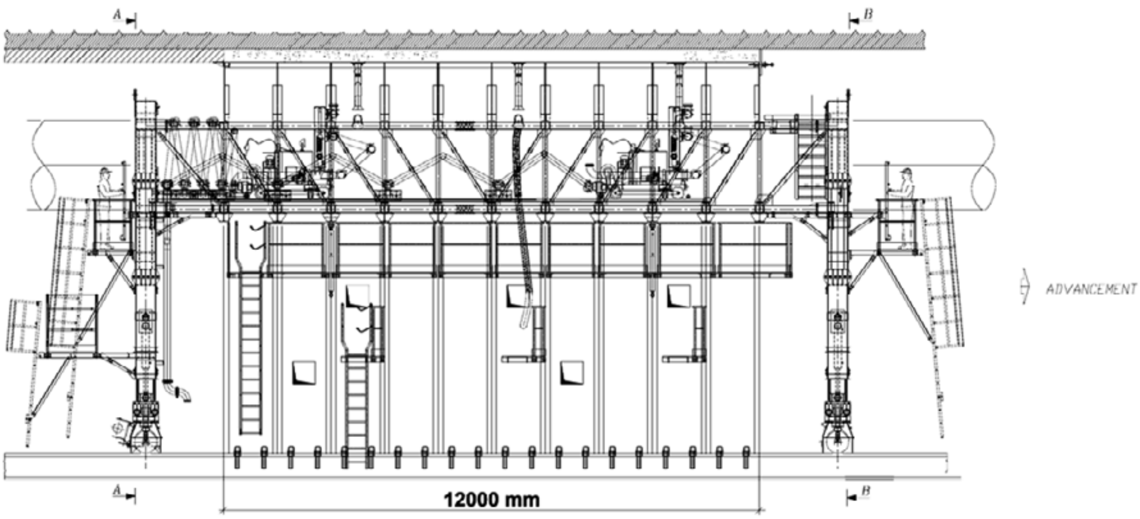

Figure 11. Carrier design

Figure 12. Formwork assembling operation

Furthermore each forms is provided with its integrated vibration system, mainly composed of one compressed air feeding net, to which a series of 48 pneumatic vibrators is connected. Each vibrator is applied on cradle welded on the reinforcements foreseen on the forms. The positioning and the quantity of the vibrators on the steel form is determined according to the area of influence generated by each vibrator with the aim to service all mantle surface coming in contact with concrete.

The feeding of the concrete is made through a series of pipes of 5” which delivers the concrete from the pump pipeline at the base of the formwork up to the concrete distributor system (DCL).

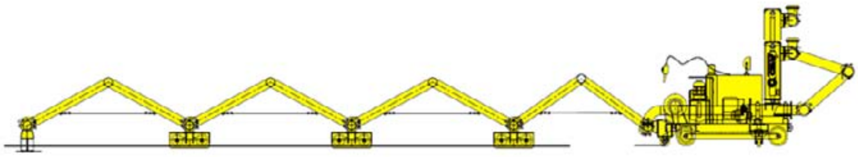

Figure 13. DCL Concrete distributor

The concrete distributor system is constituted of a trolley sliding on rails installed on the upper platform of the forms, which carry a rotating and extendable boom. The boom is provided with a terminal pipe element that is positioned and pressure-connected to the cone-shaped pipe of the pipelines and of the casting pipes, by means of the boom itself. The sliding-freedom of the trolley is granted by a pantograph articulated concrete pipe system which can compress or extend itself along the upper platform, during the translation of the trolley.

The form is also provided with a special supporting frame which has the purpose to host the air ventilation pipes. The contemporary hosting of the air pipe and the concrete distributor on the upper platform, requires the design of a particular concrete distribution system.

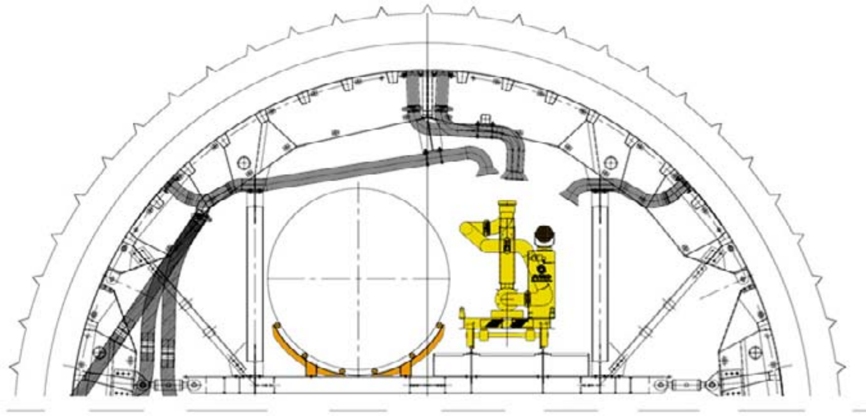

Figure 14. DCL Concrete distributor pipes approaching and ventilation pipe support

4 Conclusions

The interpretation of the necessities of the customer drives the selection of the most suitable equipment which has to be defined in respect of the project constrains, often represented by budget and time availability other than the peculiarities of tunnel construction process. Most of the time, the most suitable equipment is also the simplest and proven one which can be the most convenient both in terms of investment and in terms of operating costs. The self-supporting system formwork chosen by Gilon Tunnel Builders – (CCECC-DANYA CEBUS JV) is a clear example of a wise cost investment which can permit to achieve the performance required.

5 Acknowledgements

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