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CIVIL ENGINEERING STATUS REPORT FOR THE ATLAS & CMS WORKSITES

H. Rammer, J. Osborne

Abstract

Construction work on the civil engineering contracts at Point 1 and Point 5 started in 1998. The new surface buildings and underground structures are necessary to accommodate the ATLAS and CMS detectors for the LHC Project. The principal underground works at both points consist of two new shafts, two caverns along with a number of small connection tunnels and galleries. At Point 1, the works are 90% complete. Most of the surface buildings as well as the shafts and one of the two new caverns have been completed, and the construction of the second cavern is well underway. At Point 5, the works are 70% complete. Most of the surface buildings as well as the shafts and the pillar have been completed. With excavation of the two large caverns complete, the concreting of the final linings has started. The aim of this paper is to present the status of the civil engineering on these worksites and in particular the challenges encountered constructing the experimental caverns.

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1 INTRODUCTION

The civil engineering works for the LHC Project are divided into four main Packages. Package 01 consists of all the underground and surface works at Point 1 necessary to accommodate the ATLAS detector. Similarly Package 02 is at Point 5 to accommodate the CMS detector. This paper will present the status of these worksites since the start of construction in 1998.

1.1 Package 01 - Principal Civil Engineering Works

The principal surface works consist of the SX1 experimental hall, a 84 m long and 24 m wide steel building, providing access to the shafts PX14 and PX16. Similarly, the new SDX1 building is providing access to the PX15 shaft. Two concrete buildings, SUX1 for cooling and ventilation equipment, and SH1 for cryogenics equipment, are to be built adjacent to SDX1. Other new buildings include the SCX1 for offices, SGX1 for gas supply, SE1 for electrical equipment and the SY1 building for security control as well as the SF1 cooling towers.

The underground works for Package 01 consist of the two new shafts PX14 and PX16, 18.0 m and 12.6 m in diameter, providing access to the new experimental cavern UX15. This main cavern with internal dimensions of 30 m in width, 35 m in height and 55 m in length, is to be built with its axis parallel to the beam tunnel to house the ATLAS detector. The USA15 service cavern is situated perpendicular to the UX15 cavern. USA15, with a spring line diameter of 20 m and a length of 62 m, is connected to the PX15 shaft. PX15 is an existing unlined shaft from the LEP construction of about 10 m in diameter, providing the main personnel access to the new underground structures. Various smaller access and services tunnels provide connections between the UX15 and the USA15 caverns.

1.2 Package 02 – Principal Civil Engineering Works

In April 1996, the design and supervision was awarded to Gibb(UK), SGI (Switzerland) and Geoconsult (Austria) for approximately 12MCHF. After tender negotiations the construction contract was awarded to a joint venture of Dragados (Spain) and Seli (Italy) in May 1998 and work on site commenced 31 August 1998.

The principal surface works consist of the partial demolition of existing surface buildings to make way for the new 140m long SX5 building for the detector assembly. This building has two 80t cranes internally and a large temporary external crane over the shaft for lowering the detector sections, weighing up to 2500t each. Due to the high loadings from the detector, the floor slab needs to have piled foundations. Other new buildings include the SF5 for cooling & ventilation, SGX5 for gas supplies, SUX5 for ventilation, SCX5 for offices, SH5 for cryogenics, SDX5 over the smaller access shaft and the SY5 building for security control.

The principal underground works at Point 5 consist of two new caverns, two new shafts of 20.4m and 12.0m internal diameter, a number of smaller connection and service galleries and tunnel enlargements on the existing LEP. The new experimental cavern UXC55 (26.5m wide and 24.0m high) and the service cavern USC55 (18.0m wide and 14.0m high) are parallel and in close proximity of each other. The rock cover to the main cavern is only around 20m with an overburden of about 50m of water bearing moraine above. To allow excavation of the shafts to proceed it is therefore necessary to freeze the ground, with excavation and lining in stages and a second lining added later. The main features with regard to special construction techniques is that it is necessary to replace the rock between the two caverns with a 7m thick concrete support pillar and that the works must proceed in conjunction with LEP operations until final shutdown.

All the spoil generated from the excavation will be permanently stockpiled on the site in accordance with the requirements of an external landscape architect. This will considerably reduce the amount of construction traffic on the public road network.

2 SURFACE WORKS PROGRESS

2.1 Package 01 - ATLAS Civil Engineering Works

Work at Point 1 commenced in April 1998 with the construction of the SX1 building. The SUX1, SE1 and SY1 buildings were constructed in parallel. Following completion of the SE1 and SY1 buildings end of 1998, the contractor started construction of the SCX1 and SGX1 buildings.

The SUX1 building was completed and handed over to CERN in August 2000. Completion of the SCX1 and SGX1 buildings followed in January 2001.

The construction of the SF1 cooling towers started in February 2000, and the structure was completed in December 2000.

The construction of the SDX1 and SH1 buildings commenced after completion of the USA15 cavern and the installation of the precast concrete modules in the PX15 shaft in January 2002. The buildings were completed and handed over to CERN in September 2002.

The SX1 building has been partially completed in February 1999 with base slab, steel structure, wall cladding and roofing, such that the building could provide a secure, weatherproof and sound insulated covering to the shaft excavation area inside the building. The outstanding works in this building will be carried out after completion of the underground works in May 2003.

2.2 Package 02 – CMS Civil Engineering Works

The SX5 building was handed over to CMS on schedule at the beginning of 2000. At the same time the SH5, SD5 modifications and the SY5 building were also handed over along with the associated technical galleries and access roads.

Subsequent to these structures, the contractor started construction of the SF5 and SUX5 buildings for cooling and ventilation. The SUX building, which is adjacent to the new PM54 shaft, was delayed due to the problems encountered with the ground freezing. However, both building were completed along with the foundations for the helium tanks by mid 2001.

Originally the SGX5 building for gas supply was not due for completion until the end of 2003. However, this structure was also handed over in mid 2001.

The outstanding surface works consist of the prolongation of the SX5 building over the PX56 shaft, the SDX5 building over the PM54 shaft and the SCX5 building for the physicist's controls. The construction of these remaining surface building will not start until after the near-completion of the underground works in 2003.

3 UNDERGROUND WORKS PROGRESS

3.1 Package 01 - ATLAS Civil Engineering Works

3.1.1 Construction of PX15 and USA15

The construction of the USA15 cavern was carried out from the existing PX15 shaft. Prior to the excavation in USA15, the primary support of PX15 had been repaired and a waterproof membrane and a new inner concrete lining were installed in the shaft. These refurbishing works in the PX15 shaft were carried out between November 1998 and May 1999.

Construction of USA15 followed with excavation and primary rock support. The excavation sequence was vault excavation in two headings, followed by bench excavation and invert excavation. Concrete works followed in March 2000 with the construction of the base slab, vertical sidewalls and the southern end wall. In parallel, the deep section under the PX15 shaft was excavated and concrete lined, and a waterproof membrane was installed in the cavern.

The construction of the concrete vault started in January 2001. The vault lining was installed in eight sections of approximately 8 m in length each. Erection of the formwork, placing of the reinforcement and concreting took three weeks per section in average. The northern end wall of the cavern was constructed in parallel with the concrete vault.

Both the PX15 shaft and the USA15 cavern were handed over to CERN in July 2001.

3.1.2 Construction of PX14, PX16 and UX15

The excavation of the two shafts PX14 and PX16 started in February 1999 after the partial completion of the SX1 building. Excavation and installation of primary rock support (shotcrete and rock bolts) was carried out in both shafts simultaneously. The bottom of the shafts was reached in August 1999. Reinforced concrete collars were constructed at the intersection between the shafts and the cavern vault, requiring additional excavation, primary support, anchoring into the rock and concreting.

Installation of the waterproofing system and the inner concrete lining followed, using the slipforming technique. These works were carried out in sequence, starting with the larger PX14 shaft. The first shaft was completed in April 2000, and PX16 was completed four months later.

Excavation in the UX15 cavern vault commenced immediately after completion of the PX14 shaft. The 35 m wide vault was excavated in five headings, starting with the outermost side drifts along the southern and northern sidewalls, followed by two intermediate headings and finishing with the excavation of the central heading. Vault excavation, including primary rock support, was completed in October 2000, followed by the installation of the waterproof membrane.

Excavation in the UX15 cavern was suspended to allow the construction of the concrete vault. The concrete works commenced with the construction of the reinforced concrete crane beams and the upper end walls. In January 2001, a large scaffolding structure for the support of the vault formwork was erected in the cavern. Concreting of the cavern vault followed, and a total of seven sections of approximately 8 m in length each were installed. The construction of the reinforced concrete vault lining was completed in July 2001.

Prior to the re-start of the excavation works in UX15 under the completed concrete vault, pre-installed cable anchors had to be tensioned to take the load from the dead weight of the concrete vault. A total of 38 anchors of 2200 kN capacity were installed between four anchor galleries, excavated from the PX14 and PX16 shafts above the UX15 cavern, and the concrete vault itself. The lower (passive) ends of the anchors were cast into the vault concrete, and the upper (active) heads were left accessible in the anchor galleries. In August 2001, the anchors were successfully pre-tensioned to their working load, and excavation could re-commence.

Bulk excavation in UX15 was carried out in 3 m high benches. Excavation was carried out down to the level of the existing LEP tunnel. On October 10, 2001, the LEP was broken into. The excavation works in the UX15 cavern were again suspended at the level of the existing tunnel to allow the construction of the UJ13 and UJ17 caverns. Various smaller connection galleries between UX15 and USA15, as well as survey galleries between UX15 and UJ13/UJ17 were constructed in parallel.

The excavation in UX15 re-started in February 2002 and reached the final invert level in April 2002. The construction of the inner concrete lining followed, consisting of a 5 m thick reinforced concrete slab and 2 m thick walls. The construction of the base slab was carried out in three major lifts of approximately 1.5 m thickness each, plus three minor concrete pours to form various trenches within the slab. The slab was completed in October 2002, however construction of the sidewalls and endwalls already started beforehand in September 2002 with the installation of the reinforcement for the first lift. The walls were then constructed up to the underside of the pre-installed concrete vault in six lifts using 4 m high formwork panels. The wall lifts were split into two halves, and the average rate of progress was two weeks per half.

At the time of writing this paper, the concrete walls are substantially complete. A grouting operation will follow to inject the void between the top of the walls and the underside of the concrete vault. Thereafter, the tensioned anchors will be de-stressed to transfer the weight of the vault from the anchors onto the concrete walls. The Low Beta Shielding tubes are due to be installed at the intersections of the beam tunnel with the cavern end walls. The tubes weighing approximately 55 tons each will be installed onto already part-completed concrete blocks and supporting columns. After accurate alignment and securing of the tubes on the blocks, the tubes will be embedded in concrete by a subsequent concreting operation. The UX15 cavern is due for completion by the end of April 2003.

3.2 Package 02 – CMS Civil Engineering Works

3.2.1 Shaft Construction

It was decided to utilise the technique of ground freezing to enable the construction of the two new shafts. The shafts are approximately 100m deep and pass through approx. 50m of mainly sandy gravel material, namely Moraine before reaching the Molasse rock. Aquifers exist in the upper and lower gravel strata.

The basic principle of ground freezing is to remove heat from the ground until the temperature is below the freezing point of the groundwater system, allowing a vertical cylindrical ice-wall to form around the perimeter of the shaft prior to excavation. In order to achieve this it was necessary to drill and install freeze pipes around the perimeter of the shafts in order to reach the Molasse. Brine was then circulated in the freeze pipes at a temperature of around –23°C in order to achieve an average frozen ground temperature of approx. –10°C. The refrigeration plant consisted of compressor system charged with ammonia. Due to the noise emissions from the plant a concrete block wall was erected around the installation.

Pre-grouting was performed in order to combat the effect of groundwater flow in the existing aquifers in order to reduce the velocity of the water to acceptable levels. This grouting of cementitious bentonite mixture was controlled using a volume and pressure criteria.

Brine circulation started in April 1999 around the smaller PM54 shaft and by the end of June the ice wall was substantially complete. Similarly, by the end of 1999 for the PX56 shaft. However, due to the unexpected high velocity of the existing groundwater in very small and isolated pervious gravel channels it proved very difficult to close the ice walls 100%. With a combination of liquid nitrogen injection and additional grouting both shafts were successfully frozen allowing excavation of both of the shafts to be completed mid 2000. Both shafts then had their definitive secondary linings installed using the slip forming technique, allowing the ground freezing to be switched off.

3.2.2 Pillar Construction

It was necessary to replace the relatively weak Molasse rock between the two new caverns with a 7m thick concrete pillar prior to allowing excavation of the caverns to commence. Upon completion of the PM54 shaft it was possible to start construction of the pillar in mid 2000. Originally the Contract foresaw that the Pillar should be constructed from the bottom up in a series of ‘drift’ excavations followed by concreting prior to started the next ‘drift’ in order to restrict movements in the LEP tunnel. Due to revised timing of the LEP shut down an alternative method of construction was accepted whereby the pillar was 100% excavated prior to filling with concrete. The pillar excavation was complete by March 2001 and filled with concrete by September 2001.

3.2.3 Cavern Construction

Instrumentation results both during and after concreting of the pillar indicated unexpectedly high movements in the side walls of the pillar. This led to a review of the underground design and to certain changes being introduced to the primary and secondary linings of the caverns. For example, the thickness of the shotcrete linings and the capacity of the rock bolts were increased.

The first activity in each cavern was to construct an anchored shotcrete ring at the intersection between the shafts and the cavern vaults using post tensioned rock bolts. Then the excavation of the top headings started at the end of 2001.

Four further drifts were excavated for the UXC55 Cavern followed by the construction of the 3m thick reinforced concrete invert. This invert was excavated and then concreted in five bays to reduce ground movement. Further to the re-design for the caverns, heavy reinforcement was introduced into the inverts. By the end of 2002 the structural inverts for both the caverns were complete.

At the time of writing this paper the wall concreting for the UXC cavern is approx. 30% complete after which the concreting for the crown will commence. Concreting for the cavern is due to be complete by the end of 2003. The walls of the USC cavern are 80% complete and preparation work

for the crown has just started with the erection of an access platform to allow fixing of the reinforcement. This cavern is due to be handed over to CERN at the start of 2004.

The planned completion dates for the RR53 and RR57 caverns is April 2003. The handing over of all the underground works including the new UJ and RZ caverns is planned for mid 2004.

4 CONCLUSION

At Point 1, the works are 90% complete. Most of the surface buildings as well as the shafts and one of the two new caverns have been completed, and the construction of the second cavern is well underway. The completion date for all the works is May 2003. At Point 5, the works are 70% complete. Most of the surface work as well as all the underground excavation is complete. The programmed completion date for all the works at Point 5 is early 2005.