EUROPEAN ORGANIZATION FOR NUCLEAR RESEARCH
ORGANISATION EUROPÉENNE POUR LA RECHERCHE NUCLÉAIRE

CERN - ST Division

ST-Note-2003-044
4 April 2003

CONSOLIDATION ON CIVIL ENGINEERING AND TECHNICAL INFRASTRUCTURE

P. Alves, M. Nonis, P. Pepinster, W. van Baaren

Abstract

The use and age of the civil engineering structure (office buildings, halls, tunnels) and of tertiary technical equipment (mainly HVAC and electricity) at CERN is such that their renovation must be considered in the near future. Due to the large number of buildings and equipment in these conditions, and the restricted budget available it is extremely important to define priorities. The aim of this paper is to give an overview of the current conditions and the related problems, based on data analysis of CERN database and confronting it with the inventory made at CERN by an external company. After having identified the most frequent problems and repairs to carry out, a planning for intervention is therefore presented optimizing the safety aspects, maintenance costs and comfort for the users. The timescale of this intervention is related to the money that will be available in the coming years.

Presented at the 6th ST Workshop
Thoiry, France, April 1 – April 3, 2003

1 INTRODUCTION

CERN has been created in 1954 and has continuously added new installations following the new research programs that requested an appropriate technical infrastructure. An important part of CERN equipment has now reached the standard lifecycle and it is becoming more and more important to establish a consolidation plan to compensate the ageing of the installations.

CERN patrimony can be divided into two categories according to the influence the installations have with respect to the functioning of accelerators: « machine » equipment is the equipment strictly related to the accelerators and whose malfunction has a direct effect to the running of the accelerators; « tertiary » equipment is the one that is related to all other installations.

This paper focuses on the tertiary equipment: office or workshop buildings, technical installations for HVAC, electricity. An overview is also made for the need of consolidation on the civil engineering related to the tunnels where the accelerators are located. Standard minor refection of general infrastructure (roads, pavements, fences) is not part of this paper; the cleansing network is only mentioned in the last paragraph and shall be object of a separate document.

The starting points of the analysis are the backlog on MP5 (CAMM software used for the management of all the maintenance on the technical infrastructure at CERN) and the inventory carried out by an external company from May to August 2002. Finally, all the problems reported for some specific buildings have been checked on site for validation.

An analysis of the most important problems is done in the following for each sector of activity, detailing the typology of intervention needed for the next years and an estimation of the related costs is presented. It has been chosen to present a limited consolidation planning, since the amounts for a global intervention are high and have to be foreseen on a long term basis.

2 CIVIL ENGINEERING

2.1 Tertiary buildings

Tertiary buildings cover an area of 168’700 square meters and represent 47% of the 574 surface buildings. With the first of these buildings being constructed in 1954 the range of age of these infrastructures is very large. The figure 1 presents the percentages of analysed buildings by age category:

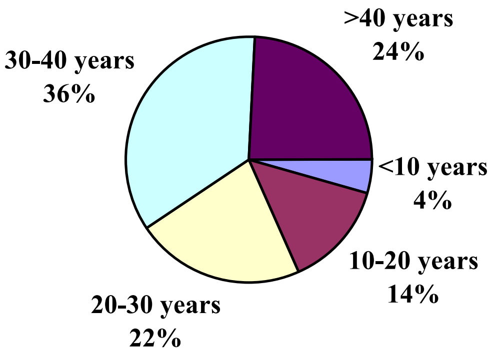

Figure 1: Tertiary buildings age category

It is generally considered that the average lifecycle of a building, after which the maintenance costs start to become important and therefore a major renewal has to be foreseen, is around 30 – 35 years from the construction; therefore more than half of CERN tertiary buildings are included into this category and in 10 years time the percentage will increase to more than 80%. At present no preventive maintenance is performed on the civil engineering; interventions are corrective following the detection of a problem or of a malfunction.

Proper maintenance can minimize the rate of deterioration, but in the next years the problems cannot be eliminated without a specific consolidation project.

The buildings presenting problems are shown in figure 2, divided by typology:

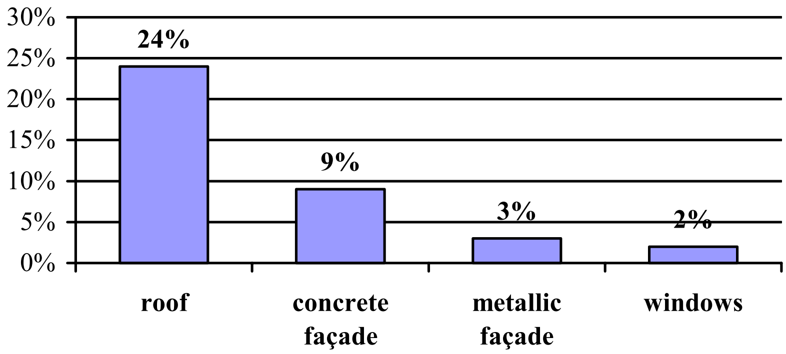

Figure 2: Percentage of buildings presenting the most frequent problems, divided by typology.

The principles to establish the priorities for intervention are the following:

- Presence of safety problems,
- Magnitude of the problem detected,
- Strategic importance of the building and future use in the next years,
- Cost estimation,
- Comfort conditions for users

Some interventions have already been carried out in the past years (for an overall amount of 2 MCHF), but this was not enough to compensate the general deterioration of the buildings; a more important campaign is necessary in the coming years.

In the next paragraph a short overview of the most important problems is given.

2.1.1 *Roof*

The most frequent and serious problem on civil engineering is represented by roof waterproofing: the number of roofs repairs per year has increased since 1995 (see figure 3) and is now more than the double with respect to 4 years ago.

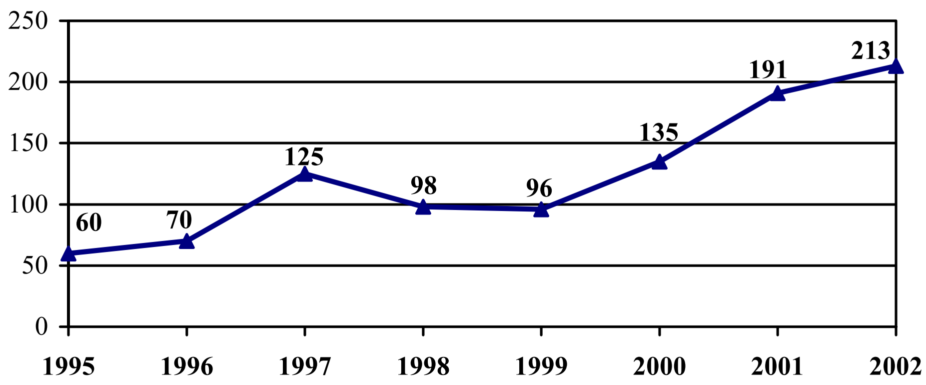

Figure 3: Number of roofs interventions per year.

We consider that around 20 buildings need a short term repair for an area of 19’000 m^2 (over a total area 35’500 m^2). The overall cost is 3 MCHF that need to be spent in the next 4 years at maximum; delaying the intervention can bring the damage to a more severe situation and request bigger expenditures in the future.

2.1.2 Concrete façades

The deterioration along façades is mainly due to carbonation that leads to the corrosion of the steel reinforcement, which causes the cracking, spalling, and delamination of the concrete. Other than the aesthetic impact, the problem is mainly focused on the safety issues related to pieces of spalled concrete falling from buildings, and to the durability of the concrete: once the steel is exposed to air the deterioration accelerates until the bearing function of the wall is seriously damaged.

In this case a more important campaign, in terms of number of buildings concerned, has to be foreseen; the surface interested is however important and the extension of the problem can only be guessed since not all the damages are clearly visible. A sample analysis should be envisaged to have a full and precise picture of the existing situation.

The urgent renovation to foresee in the next future interest 8 tertiary buildings for a total area of 4’800 m^2; 865 CHF should be at least foreseen to that purpose.

Building 172 has a large crack that extends from the walls to floor; this crack can affect the structural integrity of the building. At present a detailed evaluation is underway to determine the severity of the problem and allow cost estimation.

2.1.3 Metallic cladding

Metallic cladding of some of the buildings needs a renovation. The problems encountered are related with corrosion, scaling painting and fastening of some parts of the cladding that can lead to water penetration, faster deterioration of the elements and danger of falling pieces, the average cost for intervention is 100 CHF/m2.

2.1.4 Windows

There are around 20 buildings whose windows are in such conditions not to provide the necessary functionality (water and air tightness).

Bldg.	Roof		Façade, cladding		Others	
	Surface [m^2]	Cost [kCHF]	Surface [m^2]	Cost [kCHF]	Surface [m^2]	Cost [kCHF]
13	750	130			280	11.2
31			200	36		
36			936	170		
30			2153	387.5		
60			100	18		
102	880	140	300	54		
112	810	130				
113	1275	200				
166	380	65				
168			700	126		
181	1425	213				
186	2085	333.6				
191/192			175	31.5	400	32
376			360	65		
510	714	85.6				
867	2980	476.8				
Total	**9’214**	**1’774.7**	**4’924**	**888**	**680**	**43.2**

Table 1: Summary of building necessitating the most urgent intervention, divided per typology, cost and surface concerned

2.2 Machine buildings

Machine buildings represent a total surface of 204'000 m^2; their strategic importance is directly related to the influence on the running of accelerators. The safety risks related to defects are in general bigger, especially in the case of structures containing electrical substations.

The problems encountered with these buildings are similar to those of the tertiary buildings.

2.2.1 Meyrin Site

The average age of the machine and accelerator buildings on the Meyrin Site is about the same as that of the tertiary buildings. In 2002, one roof consolidation has been undertaken (building 2001, about 900 m^2). The large majority of the buildings affected by carbonation are related to machines (sub-stations, cooling towers, etc.). One of them (274) has been treated in 2001 while three others are scheduled for this year. Seven buildings still need to be done in the next 5 years for a global cost of 500 kCHF.

2.2.2 SPS

The SPS was built in the early seventies, which means that the surface buildings will soon reach the critical age of 30 years. A diagnostic of the roofs of all SPS buildings (BA1-7, BB3-5 and BE61) conducted in 2001 pointed out that the waterproofing of all buildings was in a very bad state and needed to be replaced urgently. In 2002, the roof waterproofing of four of these buildings has been replaced (BA1, BB3, BB5 and BE61), representing 5000 m^2 in total. For this year, the consolidation of the BA4 roof is foreseen (1400 m2). More than 10'000 m^2 therefore still need to be done representing an expenditure of almost 2 MCHF.

Two SPS buildings are seriously affected by the carbonation problem, i.e. the cooling towers 863 and 893. In 2001, the first has been treated. Consolidation of the second is scheduled for this year.

2.2.3 LEP/LHC

The age of the LEP buildings is about 15 years. The roofs (60000 m^2 in total) are still in relative good conditions and will normally not need to be replaced in the coming 10 years.

The first LHC building was delivered in 1997 (SW18); the last one will be handed over in 2005 (SX5). The LHC buildings have a guarantee period of ten years for the roof waterproofing (two years for the other components); therefore repair costs have to be foreseen starting from 2008 and major intervention on roof waterproofing (20000 m2 in total) will not be necessary before 2020.

2.3 Underground structures

As for the surface, CERN does not have a preventive maintenance program for its underground structures. Punctual problems are repaired in an ad-hoc manner and these usually consist in repairing cracks and water leaks. Long-term tendencies, such as the heave of the tunnel invert, may make major consolidation works necessary.

2.3.1 Water leaks/drainage

In underground structures water leaks regularly occur, independent of the age of the structure. They are repaired on demand during the shut-down periods.

The annual budget for this type of works is between 20 and 50 kCHF.

2.3.2 Tunnel heave

The tendency of underground structures to heave in swelling rock is a known phenomenon. This swelling mechanism is due to water associated to a reduction in stress. The excavation of a tunnel, inevitably, cancels or reduces very strongly the vertical stress in the invert slab. If for any reason some water occurs the swelling starts. After the concreting of the lining, the swelling of the soil may continue and produce stresses on the invert, especially the slab, which may result in cracks and heave up to several centimeters. In some cases the heave process can continue for decades.

Most of the tunnels at CERN are excavated in molasse rock, which is known to be potentially swelling. In the past, heave of the invert slab has occurred in several tunnels (especially in the SPS), which necessitated in some cases the demolition and reconstruction of parts of the slab.

More recently, during the construction of the LHC, heave has occurred in the TI2 tunnel and in the UD68 cavern. In both cases it occurred during the excavation phase (related to the presence of water) and (partial) reconstruction of the slab has been undertaken.

Given the slow progress of heaving, this may cause problems again in the future requiring major repairs. Nevertheless it is very difficult to predict if it will occur and in which extent.

2.3.3 Consolidation works

In the last 2 years 2002, several major consolidation works have been undertaken in the former LEP underground structures:

- Reinforcement of the UX45 headwall (1'500 kCHF).
- Reinforcement of the UX85 headwall (1'200 kCHF).
- Reinforcement of the LEP Jura tunnel (1'600 kCHF).

For budgetary reasons, the reinforcement of the UX65 headwall (700 kCHF) has been postponed.

In fact, these works should be considered more as an improvement of the initial structures, rather than consolidation since the UX headwalls were not designed to resist to the ground pressure as it appeared later. The Jura works are a resolution of previously unsolved problems at the time of the LEP construction.

3 TECHNICAL INFRASTRUCTURE

The technical infrastructure needing the most important work on consolidation in the next years for the tertiary installation mainly concerns the HVAC and electrical equipment; doors renovation interest a reduced number of equipment and the amount required are lower.

As for the civil engineering aspects, the age of the installations has reached for most of the cases the standard lifecycle and, in addition, safety or environmental requirements have been modified (ex. CFC replacement on air handling units, asbestos), requesting the performance of additional interventions on installation otherwise still in good conditions.

3.1 Heating, ventilation and air conditioning

The consolidation works to be carried out in the field of HVAC can be classified in two categories:

3.1.1 Control systems

The control system of the major part of the HVAC installations is out of age: a study in 1999 already showed that more than 100 installations (dated from 1957 to 1980) were concerned by the impossibility to find any spare parts. Since then, only 4 of them have been renewed: buildings 3, 30, 103 and 892.

More over, the first systems that have been renewed in the eighties, belonging to a more recent category, are already obsolete.

This situation exposes to major breakdowns on heating of office buildings, for example, and to operate heating manually all along winter as it was the case last year for building 892 and this year for building 31. This leads to major operation constraints, users' complaints and to excessive cost in the energy consumption for heating.

3.1.2 Equipment

HVAC equipments suffer different problems due their age:

- <u>Obsolescence</u>: many equipments among which are air conditioners and chillers show worrying signs of an impending end of life, and their function cannot be guaranteed anymore, for example the air conditioning system of the print shop in building 510 (a strategic activity at CERN), where any failure of the machine can occur at any time and stop the activity for weeks or months, presents corroded equipment and spare parts are not available on the market anymore.

Some equipment has already been replaced in the last years: chilled water production in bldg 13, heating in bldg 304, air conditioning in bldg 60, 6^{th} floor. Among the one to be done there are the chillers in bldg 24 and 101, the air conditioning in bldg 510, the heating regulation in bldg 31.

- Presence of asbestos: a few air handling units are still insulated with asbestos panels. Though it has been checked that there is no scattering of noxious particles in the rooms of which they control the temperature, the maintenance on these devices makes technicians work periodically in direct contact with asbestos. A partial renovation program has been led from 1998 to 2000 but needs to be completed (air handling units in bldgs. 3, heating substation bldg 30)
- Corrosion of pipe lines: this problem is much generalized on CERN piping networks, but recent and recurrent failures on the superheated water network (110°C) for the remote heating has shown that renovation works must be launched on very short term. The problem also exists on several sanitary hot water distribution pipes. Several leaks on the different networks have been fixed in a temporary way for years, waiting for a definitive repair.
- Hygiene of sanitary water distribution: this is a problem on the large production plants (mainly the one of the Main Building area) which were built up in the beginning of CERN. They are now over dimensioned and underused and the temperatures cannot be kept at standard level. As a consequence, conditions for spread of corrosion and development of microorganisms (Legionella) are met. The refurbishment of the systems, including the part related to restaurant n°1 and in building 13 must be planned.

3.2 Control and power supply switchboard in heating plant in Prevessin.

The present control and low voltage supply switchboards in building 860 have been commissioned in 1974; the most important problem existing is the obsolescence of the equipment and the lack of spare parts: whatever main problem will occur it might be impossible to restart the plants without a complete renovation of the installation.

The switchboards are feeding two main plants: the heating plant of Prevessin (running generally from September to May) and the compressed air plant that provides with compressed air all the SPS complex, the Prevessin' site and the North Experimental Area (running mainly from April to October, test period excluded).

The power supply units (Hazemeyer, "Tiratole" model) have been replaced on the market by more updated equipment and spare parts are no more available. The cabling presents also some problems since all the cables from the medium voltage transformer are composed of halogenated insulation whose use is now forbidden at CERN; in addition an important number of cables are no more used, since the burners, originally used with fuel, are now supplied with gas, with a different number and typology of probes, sensors etc.

The control system needs to be upgraded since the existing equipment "Telemecanique" is obsolete and no spare part is available on the market: any breakdown is at present solved by taking some spare modules from installations that are not working. A solution with a PLC has therefore to be foreseen in order to assure an updated and proper operation of the plants.

Since the existing configuration is unified in one single switchboards (containing the power and control part) and has one unique alimentation for the two plants, it is not possible to carry out the work in separate steps, according to the operation needs; all the work has to be performed in the same moment (during summer) creating a temporary supply for the compressed air plant.

The only existing equipment that does not require an intervention is the auto control system.

The amount of the intervention has been estimated in 1 MCHF with the following breakdown:

- Electrical switchboards, cabling: 250 kCHF
- Controls: 750 kCHF
- Dismantling, others: 100 kCHF

3.3 Electrical installations.

3.3.1 Low voltage switchboard

About 15% of the 1100 switchboards in operation are out of safety rules and standards, and have been qualified as "dangerous" at the moment of the inventory. The electrocution for operation personnel by direct contact with element under voltage is the major risk.

The renovation of these switchboards launched a few years ago, has to be restarted as soon as possible.

3.3.2 Lighting equipment

Among 635 street lighting masts that have been checked, 10% present some serious damages, either corrosion of the mast it self (risk of fall), or electrical problems due to ageing: they must be replaced for evident safety reasons. Obsolete technical equipment has been replaced in the last 2 years, mainly concerning lighting in technical galleries and office buildings.

From a general point of view, lots of equipments in tertiary buildings are obsolete (no more spare parts available) and present some risks for people safety.

3.4 Estimation of the necessary budget for the next years

Equipment	Budget needed per year	Duration	Total
HVAC - replacement of obsolete equipment	300 kCHF	5 years	1500 kCHF
HVAC - renovation of control systems	300 kCHF	5 years	1500 kCHF
HVAC - eradication of asbestos	200 kCHF	2 years	400 kCHF
HVAC - renovation of piping networks	100 kCHF	5 years	500 kCHF
Heating and compressed air plant Prevessin	1000 kCHF	2 years	1000 kCHF
Electricity – renovation of Low Voltage Switchboards	150 kCHF	4 years	600 kCHF
Electricity – Replacement of Lighting equipment	150 kCHF	4 years	600 kCHF

4 CLEANSING

The cleansing network is composed of settlement tanks, oil and grease separators, septic tanks, drainage for waste water, sewage and rain water etc. The buried network can be estimated being more than 100 km long, with dimensions from ND10 to ND1000.

Several pipes are in bad condition and one of the potential major risks is the mixing of different waters since the pipes cannot be considered any more tight proof to external infiltration. CERN has started a detailed inventory of the existing network and its present conditions: a consolidation project shall be established in the coming months.

5 CONCLUSIONS

The result of this analysis gives the clear indication that consolidation on tertiary installations is becoming more and more strategic and needs high investments. A postponing of the intervention is can only lead to a higher malfunction and is transformed in higher repair costs. All the equipment is concerned by the problem: from civil engineering to cleansing and HVAC and electrical equipment.

Since the amount are high it is not possible to establish a short term plan that can include all the installations in bad conditions; a medium term plan for the next 10 years has to be approved in order to allow CERN to guarantee an acceptable number of intervention and to recover the situation and avoid new problems; all this taking into account the budgetary constraints that CERN has to face during the LHC construction phase.