INTERNATIONAL FORUM ON SPORTS INSTALLATIONS

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THE PALAVELA

Sports Installation for Skating, Dancing and Short-track Competitions at the Torino 2006 Winter Olympic Games[1]

by

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[1] **Only text version available.**

FOREWORD

Palavela: February 2002 Call for Design Tenders – January 2005 works end

Just over one thousand days, as specified in the General Action Time Programme of Figure 1 from preliminary design start to delivery of the complete works worth some 55 million Euros overall and completed in compliance with the Merloni Law. The objective reached by the Torino 2006 Agency that seemed well-nigh impossible considering the average time Public Administrations normally take to complete such a great enterprise could certainly not have been achieved without full and complete cooperation of all the public and private Parties involved. The main target was completing works for the new sports installation planned to enable carrying out the pre-Olympic test-events programmed in January 2005 featuring the European Skating, Dancing and Short-track Championships

The following details the basic Torino 2006 Agency decisions and the factors allowing time schedule compliance and final objective achievement with full success and satisfaction, by also describing the design steps, different action lots and crucial construction steps and lastly illustrating the main sports installation special and specialist equipment.

Foto a colori

Palavela - May 2003

Foto a colori

Palavela – January 2005

MAIN DESIGN STEPS

The main new installation design steps are summarised hereunder.

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Figure 1 – process general time programme

The designer submitted an initial version of the overall action **Preliminary Project** to the Agency on October 10 2002; Toroc simultaneously underscored the need to get as close as possible to 10,000 seats and that works end be set for December 2004.

Two solutions were then envisaged to solve the issue of capacity:

- solution A - 8955 seats and 3 metres viewing distance
- solution B - 9129 and 3.5 metres viewing distance

with a request to Toroc for approving the solution chosen.

The Organising Committee stressed minimum capacity of 9500 seats and 3.5 metres viewing distance.

In January 2004, the designer gave the Agency a preliminary project reviewed in compliance with Committee requests.

The overall preliminary project complete with the changes as mentioned above was then forwarded on January 10 2003f or preliminary opinion to the ad hoc authorities as specified, approved by the Agency at end-January by adopting the hypothesis as suggested by the Process Manager of dividing actions into the following two functional lots to cut overall completion times:

- Lot 1 - Demolition, area clearing, all glassware removal and disposal, sail waterproofing re-construction by removing existing cover, sail refurbishing
- Lot 2 – New skating, dancing and short-track; installation

The definitive design of the new skating, dancing and short-track installation started divided into two action lots as follows:

Lot 1

The definitive project was completed and delivered by the designer on February 7 2003, forwarded to the control body and validated by such body with a favourable opinion on March 5 2003.

At the same time, the Agency forwarded the definitive project for the works involved to the public bodies responsible for issuing opinions and authorisations, namely he Regional Public Works Authority for Piedmont and the Aosta Valley, the local Health Department an Turin Municipality Building and Urban Division Hygienic Building Committee

The Agency acquired the requisite Definitive Project opinions and authorisations during the month of February 2003.

Executive programming commenced at the same time and the project reached the Agency with subsequent integration also following on the outcome of in-progress checks and controls during the first week of March 2003.

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Figure 2 – lot 1 general time programme

The Agency approved the executive project for lot 1, namely demolition, area clearing, glassware removal and disposal, sail waterproofing re-construction by removing existing cover, sail refurbishing for Palavela restructuring on March 6 2003.

Lot 2

On February 24 2003, the Agency advised the designer of its decision to go ahead with lot 2 operations with an integrated contract in compliance with Article 19 item 1, letter b), item 4 of Law 109/1994 and any addition thereto, so design would be at the definitive and not executive level.

The designer made an initial partial delivery of the definitive project to the Agency on March 15 2003.

That same date the Agency forwarded the definitive project for related works to bodies responsible for opinion and authorisation release, namely the Public Works Upper Committee, the Provincial Committee Public Show Premise Vigilance, the Provincial Fire Fighting Command, the Piedmont Region NHS local health authority ASL 1, Turin, the Regional Agency for Town Planning and Environment Protection ARPA Town Planning Management and Planning Directorate, the Superintendent for Piedmont's Architectural and Landscape Property

The Italian National Olympic Committee Town Municipality Building and Town Planning, and Building Health Divisions Sports Installations Committee, and finally acquired Building Permit Nr. 774/2003 of September 29 2003 on October 1 2003.

The project papers progressively acquired by the Agency were forwarded to the inspection body for definitive project checking the final approval of which was received by the Agency on June 23 2003, which simultaneously predisposed technical and administrative paperwork for integrated contract completion.

On September 25 2003, the Process Manager instructed the Contractor to commence works executive design, since the Agency had assigned the contract on September 24 2003.

The ATI executive project was approved on April 9 2004.

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Figure 3 – lot 2 general time programme

Video board Cube System Supply and Installation Lot

In December 2003 design activity had to start for equipping the new sports installation with video board to be installed suspended at the centre of the arena.

On May 10 2004 the definitive video board project was approved and an open call for tenders made, the assignment criteria being the most economically convenient offer for executive design, supply and installation of a video board cube system complete with management software and structures at the Palavela. The call was finalised on August 24 2004.

ACTION LOTS

Lot 1

This lot covers demolition, area clearing, glassware removal and disposal, sail waterproofing re-construction by removing existing cover, sail refurbishing for Palavela restructuring.

Overall expenditure for design works completion was set at some 3.9 million Euros.

The Agency assigned the job to Edilrivvek, Covecom S.p.A. and Quadrifoglio on May 9 2003.

Works commenced on May 9 2003 and ended on November 26 2003.

The Inspection Committee issued a regular Inspection Certificate in July 23 2004.

Tre fotografie a colori

Lot 1: glassware removal

Due fotografie a colori

Lot 1: roof waterproofing

Lot 2

The lot covers executive design and construction of the new skating, dancing and short-track sports installation.

Overall expenditure for design works completion was set at some 49 million Euros.

The Agency assigned lot 2 skating, dancing and short-track sports installation executive design and construction to Fiat Engineering S.p.A., Impresa Costruzioni Rosso Geom. Francesco & Figli S.p.A., Keltermica Cordero S.r.l. on September 24 2004 after integrated call for tenders.

Works started on October 9 2003 and ended on January 12 2004 with advanced installation delivery to Toroc for pre-Olympic test-event organisation and implementation.

Fotografia a colori

Lot 2: reinforced concrete plates, roof assembly scaffolding

Due fotografie a colori

Lot 2: serpentine laying and ice track installation

Video board Cube System Supply and Installation Lot

This lot covers executive design, supply and installation of a video board cube system complete with management software and structures at the Palavela.

Overall expenditure for executive design, supply and installation set at some 1.2 million Euros.

After an open call for tenders, the Agency awarded the contract to the Company Bertelè snc and system installation was completed on December4 2005.

Due fotografie a colori

Video board installation and operation during Test Evens

REASONS FOR OBJECTIVE ACHIEVEMENT

The main decisions on which and reasons for achieving ultimate success were:

- the Torino 2006 Agency team
- design management and works completion decisions
- involvement of and cooperation with all design stage authorising bodies
- the design team
- the implementation team
- in-progress involvement of and cooperation with all bodies ensuring final installation use
- ongoing confrontation with Organising Committee Toroc and end user Turin Municipality
- careful Test Event preparatory steps and work in-progress overlap management
- construction decisions and jobsite management.

The Torino 2006 Agency Team - Agency Process Manager and Professionals

The Torino 2006 Agency working group assigned full-time to the project consists of the Sole Process Manager, a technician support the former in all technical and administrative activities and an internal Agency technical secretary, also supported by Turin Polytechnic students. The Process Manager reported directly to the Agency General Management on process actions and decisions, for monitoring work in-progress and interfacing with authorising bodies, with the assistance of the Administrative Management Contract Office for all call for tenders activities, contract underwriting and payments. Directly reporting to the Process Manager but external to the Agency were the inspection body responsible for validating projects and variation estimates and the Project Control service for constant work in-progress and completion monitoring. Besides interacting with all the functions mentioned above, the Process Manager always entertained direct contacts with designers, different lot contractors, works managers and inspectors and coordinated and managed process activity and completion reports to Turin Municipality and Toroc.

To summarise, we believe the following aspects were vital for the project:

- The Process Manager was the only reference for all persons involved both inside and outside administration at all levels and for all functions;
- The Process Manager was assisted and supported by a small technical and administrative personnel team with ensuing timely decisions, no data dispersion, complete control of the situation, confirming the Process Manager as the Process Project Manager;
- The Process Manager was always present full-time at all process steps and levels to guarantee training and consolidate a winning team in addition to having constant control over all persons and bodies involved.

Decisions for Project Management and Works Execution

Process progress was ceaseless both during design and different lot completion thanks to careful programming that provided for different activity overlap (Cf. time programme at Figure 1). In particular, the Agency's basic decisions that meant reaching objectives at times set were:

- dividing the contract into suitably configured lots: the decision to advance an initial lot of area demolition ad clearing, preparation and safety operations at works start simultaneously with lot 2 design completion. Works on both lots overlapped for about a month to guarantee job continuity without interferences or complications between the two jobsite contractors involved.
- proceeding with an integrated contract for lot 2: this enable the Contracting Station to save the time executive design would have required and to limit the risk of claims on the executive project by the designer that shared and accepted all design decision having written the project.
- predisposing the definitive project by integrated contracting lot 2 with part of the project already at the executive stage, namely the structural project for installation foundations and channels. This enables the Process Manager to also order work start at the same time as jobsite area delivery, when instructing the Contractor to start executive designing.
- proceeding with completing, validating and approving the executive project for work in-progress: the Process Manager acquired and validated Contractor executive project with work in-progress disposing executive project approval, which meant the Contractor could continue works already with an continually updated executive project approved by the Contracting Station.

Involvement and Cooperation of all Project Step Authorisation Release Managements

One of the basic acts for achieving the objectives set was to involve the following opinion and authorisation release managements ever since process start:

- Central Public Works Committee
- Provincial Public Show Vigilance Committee
- Fire Fighters Provincial Command
- Piedmont Region NHS ASL 1, Turin,
- Environment Protection Regional Agency ARPA
- Town Planning Management Division Environmental Property Department
- Architectural and Landscape Property Superintendent for Piedmont
- Italian Olympic Committee Sports Installations Department
- Turin Municipality Building and Town Planning Division Building and Health Department

Construction of the new sports installation required no change to the General Town Plan, so project approval was not obtained via a Service Conference, but opinions and authorisations were obtained individually with the ensuing release of requisite building permits. The following items were therefore vital:

- involvement and ongoing cooperation with all bodies involved ever since process start; some were even contacted by the Contracting Station at the Preliminary Design Document predisposition stage, before programming start;
- interfacing with other bodies was managed directly and coordinated by the Agency supported y designers ever since preliminary design;
- an initial opinion was obtained on the preliminary project. Body remarks as to the definitive project were accepted, so the Agency experienced no special difficulty in obtain definitive project approval by the bodies involved;

- the Agency also obtained body opinions on the executive project thereby underscoring acceptance id condition set by such bodies as the basis for definitive project approval.

The Design Team – Process Manager, Validator, Project Controller

Te main persons involved in the design stage to call for work contract tenders were the Process Manager, the Designer, the Inspection Department and the Project Control service. Designing and project validation featured tight timing inclusive of involved Body authorisation for each project step and predisposition of documents required for obtaining ad hoc body opinions and authorisations. Compliance with the above time constraints, under constant project control service monitoring was possible thanks to:

- the establishment of weekly designer and validator meetings under constant Process Manager supervision;
- project delivery by subsequent steps for in-progress validation and immediate designer acceptance of validator remarks in design paperwork;
- joint predisposition and programming of technical and administrative paperwork required for ad hoc body opinions and authorisations.

The Executive Team – Process Manager, Definitive Designer, Contractors, Executive/Variations Designer, Validator, Works Manager, Inspectors, Safety Manager, Project Controller

The number of persons involved increased markedly at the execution step; however, a well-oiled group of professionals and contractors was created and totally dedicated to achieving the final objectives. The basic activities worthy of mention at this project stage were:

- constant productive coordination and interfacing between the various functions, professions and companies; in particular immediate integration into the team formed and consolidated during the design stage of new persons and bodies involved in the executive step, namely ATI with its executive designer and inspection committee;
- the timely management of project integration and variations required during work in-progress, in full compliance with legal procedures and work completion timing;
- Agency control of the project executive and implementation process with continuous work in-progress monitoring and weekly reviews. The meant early identification and correction of any critical issue that might have jeopardised achieving work completion date.

Work-in-progress Involvement and Cooperation of all Plant Final Use Authorisation Release Managements

Ever since the project's inception, the Agency involved all Plant Final Use Authorisation Release Managements without interrupting relationships but supporting them, so important for approval of the various project steps. The Agency's strategic activities in this field were:

- organising ever since initial in-progress review start with all Plant Final Use Authorisation Release Managements for -progress work review and to allow the Contracting Station to receive and apply any remark and request for changes. All this led to obtaining final use approval very fast, at works end and during final reviews by the ad hoc authorities;

- ongoing construction paperwork updating, subject to changes due to in-progress variations, so as to have complete as-built documentation available for ad hoc authority approval, at the same time as works end;
- Another important item was ongoing Process Manager monitoring the collection of all technical and administrative paperwork required for obtaining approvals. Contractors were kept under control and pressure by means of weekly meetings chaired by the Process Manager to monitor progress in finding, collecting and preparing project paperwork and necessary certification for obtaining installation final inspection and use approval.

Ongoing Confrontation with, the Olympic Games Organising Committee TOROC and the Ultimate Plant Owner Turin Municipality

Throughout the entire process of work design and execution, the Agency involved both the final installation owner the Township of Turin and the Olympic games organiser Toroc in all basic decisions. The consequences of this MO can be summarised as follows:

- all Toroc and Township needs were assessed and satisfied;
- the Agency could obtain real time basic design decisions and in-progress changes approval;
- the Township and Toroc took part in monitoring work progress enabling the latter to programme its setup activities to actual work in-progress.

Careful Test Event Preparation and Work in-Progress Overlap Management

As mentioned earlier it was known that Toroc was to carry out a series of setups inside and outside the installation in view of the test events planned for January 2005. management of overlaps and entries by the Companies contracted by Toroc was quite delicate in a jobsite that had as many as 450 workers a day at peak operational steps. Ongoing constant work in-progress Agency monitoring enabled adequately planned addition of Toroc operations to the overall jobsite. The following items are underscored in this connection:

- Toroc actions were carefully planned at the Palavela jobsite for its setup activities and wherever possible, the Agency asked for June 2004 advanced entry to complete some operations for the Toroc installation networks inside the false ceiling;
- proper jobsite contractor safety overlap and interference management enabled simultaneous Toroc contractor and sub-contractor presence and operation with setup operators-

Key Jobsite Construction and Management Decisions

A series of executive stage construction decisions were also found to be crucial for works completion within time limits set, namely:

Foundation and underground channel completion with laying and installation during initial contractual months

The solution initially suggested by the Contractor was to consolidate the building foundation terrain with foundation poles to replace design jet-grouting. As shown by Figure 4 operational plan, this enabled the following:

- easier integration with project sub-foundation and foundation jobs for more flexible installation use and overall dimensions versus jet-grouting;

- timely underground channel network completion for main installation technological system distribution and technical island to building connection;
- the rectangular track edge and outside technical island connection ring radial underground channel construction process enabled entry of personnel working on installation technological system ever since the very first contract months.

Due fotografie a colori

Lot 2: foundations with poles and channels

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Figure 4 – lot 2: foundations and system channels execution time programme

Reinforced Concrete Plate Elevation Structures

The definitive project specified open air visible above ground elevation structures.

The contractor's proposal to use industrial caissons and high-resistance low-consistency concrete mixtures with specific SCC large grain size super-fluid additives accelerated caisson construction with diffuse reinforcements and embedded electrical equipment. The use of current concrete mixtures would have required more time both during casting vibration and subsequent caisson operations (Cf. time programme at Figure 5).

Due fotografie a colori

Lot 2: reinforced concrete elevation plates

Due fotografie a colori

Lot 2: reinforced concrete plate elevation step

Metal Reticular Perimetral Beam for Roof Support and Roofing Executive Mode

The project solution specified a reinforced concrete wall beam constrained to plates supporting the steel roof reticular structure.

Construction type decision to use a reticular steel instead of a reinforced concrete beam meant meeting structure completion timing with architectural finishing and system installation practically unchanged (Cf. Figure 5 time programme).

Process Manager work in-progress reviews and checks underscored the difficulty in meeting the works programme so he himself suggested the Contractor rapidly adopt the above solution. The decision to go ahead was made on May 15 2004 after Designer approval

The Vendor produced the first beam in 15 days and assembly proceeded as follows:

- sector "C" from June 14 to July 1
- sector "D" from July 2 to September 3
- sector "E" from July 2 to August 27.

Using a reticular steel structural element meant:

- avoiding the use of top level scaffolding to support reinforced concrete beam caissons with the ensuing advantage of greater building permeability and easier machinery access to system and architectural operations performed simultaneously with the critical roofing operation;
- completing steel beam finishing after installation by using the fibre-reinforced cement panel lining and maintaining the outside look as originally designed.

Another element was found to be essential at this stage to comply with times set; assembly of root steel tubes was completed after installation of provisional scaffolding at roof level.

This meant:

- more areas at various building levels to complete architectural and system operations;
- roof structure completion together with roof assembly.

Due fotografie a colori

Lot 2: positioning the roof support metal beam

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Lot 2: spatial roof support scaffolding

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Lot 2: spatial roof assembly

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Support scaffolding

Double Work Shifts

Starting June 2004 ATI organised operations on two work shifts that Figure 6 shows involved greatly increased jobsite manpower; also, Saturdays and Holydays were considered as standard work days and no Summer or Winter pauses were allowed on jobsite.

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Figure 6 – lot 2: personnel present

Other factors contributed to action success within times programmed

Proper jobsite safety management by all persons involved with no serous accident throughout works duration is another factor that most certainly contributed to reaching project objective, with work never having to being suspended as a consequence.

ATI decided to create an operational jobsite office independent of its corporate organisation for practically all functions, capable of operating autonomously on construction design and works execution issues.

The absence of external constraints by nearby jobsites with none of the interferences or operating complications often presented by co-existing jobsites is another factor worth underscoring.

Further stimulation to bear the sacrifices necessary to reach the ultimate objective, as felt daily on entering a jobsite, certainly was the respect for anyone involved in creating a building to be the symbol of Turin, also thanks to the fact that most professionals, Companies and labourers in the Palavela project come from Piedmont.

SPECIAL AND SPECIALIST INSTALLATION EQUIPMENT

Two special items that give the new sports installation added system value are the scenery lighting system cabling managed control to produce high scenic content show and the passive acoustic system that make the arena a high sound performance level environment.

Scenery Lighting System

Skating is not only an Olympic sports specialty but also a spectacular form of choral dancing art.

Sports events traditionally open with ice shows and close with a final Grand Gala where athletes, after completing their competitive spirit, express their personal artistic vein free of rigid programmes, protocols and competitions.

In this context, the sports installation turns into a fantastic theatre with a 60-metre long 30-metre wide stage lit up by a specific system capable of creating light effects such as to satisfy the most demanding show director.

This system consists of a lights and video complex for creating a spectacle for events held inside the Palavela. A series of so-called American spot lights suspended from the Palavela structure and

moved around by electrical motors, support the lighting bodies of the dedicated control panel to create the light show. Spot light management signals come from the light control room and can also be directed fro the track edge with an ad hoc track to light control room connection. The lighting system is provided with an alluminium structure extending over some 350 metres.

Spot lights are suspended and moved by 66 500-kilo load motors, all connected by 1000-kilo load steel cables.

Motors are powered by 11 motor-controllers, each powering 6 electrical motors, which can be moved directly by the motor-controller either individually or in groups and by the gangway from the control room or track edge via a motor-dedicated control.

The gangway carries 25 electrical control panels supplying the scenery lighting power.

Lighting bodies are of various types to achieve all required scenic effects.

Video projectors and Catalysts are also provided for special effects.

A panel inside the light control room monitors all motor-driven and conventional halogen lights.

Lights, spot lights and video projectors can also be controlled from the track side via lines reaching the central control room.

Conversely, the 3 Catalysts cannot be controlled from the track and image load and processing operations can only be performed inside the light control room.

The tracks sports lighting system that normally ensures 6.000-lux horizontal ice lighting must be darkened fast and instantaneously switched back on to make scenic requirements and TV shooting constraints compatible with live international transmissions,

Given the light type used, these instantaneous back-on switching units cannot be used with available conventional technologies and not even with the electronic devices adopted for conventional back-on switching devices that are not fast enough for the specific application, to each the colour temperature levels suitable for shooting at 5.600 °K halogen discharge.

The solution of mechanical darkening each of the 420 1000-Watt projectors with special horizontal rotating Venetian blind type wings designed especially to minimise light efficiency in the open position and simultaneously ensure the darkening required by scenic needs in the closed position.

Due fotografie a colori

Scenery lighting effects on the track

Due fotografie a colori

Scenery lighting system

Passive Acoustics

PASSIVE ACOUSTICS – SOUND ABSORPTION

Palavela use for and after the Olympic games has special sound requirements inside the arena, in particular as follows:

- reverberation time to be constrained within optimum levels referred to specific arena volume
- spectator seat sound field distribution close to the track must be as uniform as possible.

The arena roof plays an important role in obtaining the certifications listed above.

Project parameters particularly affecting roof sound response are as follows:

- acoustic absorption
- sound deadening

These parameters were optimised by careful design followed by laboratory experiments.

The roof consists of a complex system of sound insulating and deadening panels resting on a spatial reticular structure. Figure 7 shows a typical cross-section of the roof and its key material features. The roof package consists of two main elements and a sound absorbing false ceiling on the lower part and a system of sound insulating blind panels on the higher part towards the outside.

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Figure 7 –Palavela sound covering cross-section

The false ceiling consists of two neoprene nucleus coupled alluminium alloy sheet panels. The metal panels are drilled with 30mm side square openings spaced 55 mm; empty/full drilling percent is equivalent to 30%. The metal support frame is of the full fold-down hidden type consisting of an open junction with a vibration-proof steel pin. The panels support three fibreglass layers and a glass veil. This is followed by a 46mm air space limited above by the roof blind sheet panels.

The sound absorption performance required by the acoustic project was achieved by using the following sound absorption mechanisms:

- cavity resonance absorption
- porosity absorption
- deadening absorption.

A scale 1:1 roof sample was at the design stage to exactly identify false ceiling sound performance and measure reverberating chamber sound absorption (Cf. Figure 8).

A similar sample also enabled experimental testing of panel deadening features.

Class 0 50mm density fibreglass

Class 0 50mm 50 kg/mc density water repellent fibreglass
Class 0 100mm 35 kg/mc density
water repellent fibreglass covered on both sides with a double glass veil

foto a colori (?)

Figure 8 – Reverberating chamber setup for identifying sound absorption coefficient

Figure 9 shows empty versus false ceiling containing chamber reverberation time. Consistent time reduction is noted over the entire frequency range of 100 to i 4kHz, particularly at low frequency. Figure 10 shows measured versus project absorption coefficient

Tests showed that the expected project calculation panel deadening features different low frequency resonance levels, the special alluminium-Neoprene-alluminium sandwich structure and its dynamic rigidity making resonance appear evident and only slightly deadened. Free oscillation panel deadening was considered to low and it became necessary to match the metal panel with material to dampen such oscillations, namely a direct contact fibreglass panel system.

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Figure 9 – Reverberation time RT60 in empty and support

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Figure 10 – Absorption coefficient trend compared with project

PASSIVE ACOUSTICS - SOUND INSULATION

Roof sound insulation is vital for controlling noise generated inside the area during events to avoid disturbing the receptors closest to the sports installation, so the sound insulation project was developed starting from a condition of very high noise level inside the arena, very close to that of a rock concert. The project sound spectrum comes from a series of noise measurements made during a concert in an environment similar to the Palavela. It features very high energy content at low frequency and an average weighted A curve level equivalent to some 96 dB(A).

These conditions made it necessary to ensure average noise deadening of about 47 dB(A) to limit noise to the outside to about 50 dB(A) at one metre from Palavela walls; this level was taken as an initial figure for assessing sound impact on the fronts of private dwellings close to the Palavela.

Two concurrent items were worked on to obtain the average deadening required: loudspeaker system layout and false ceiling and blind roof sound insulation.

As for the former, it should be noted that sound pressure levels impinging on the false ceiling panels are much lower than those measurable at listener level and using loudspeaker giving out most sound energy to the front means deadening about 20 dB(A on the area behind them.

Sound insulation was dimensioned based on the insulation and absorption levels sound proof sheet roof The false ceiling sound absorbing part plays an important role in outgoing insulation as the fibreglass panels feature a very high sound deadening constant.

The first two 100mm thick roof sound absorbing 35kg/mc normal density fibreglass panel layers operate efficiently at medium to high frequency: the other more internal 50kg/mc density fibreglass support layer contributes to dissipating sound energy at lower frequency levels.

The type of panels chosen guarantees high sound energy deadening especially at medium to high frequency of over 20dB starting from 315Hz. The project specified increasing insulation at lower frequency levels by adding another 50mm thick 200dB/m sound deadening panel to the two 100mm thick 36dB/m sound deadening constant layers.

Extrados covering was with 80mm overall thickness steel out and micro-nerve internal layer sandwich panel with an intermediate oriented-fibre high density mineral material insulation.

WORK END IINSTRUMENTAL TESTS

Expert technicians made a series of sound measurements at work end to check compliance with project sound specifications. Some remarks on reverberation times inside the arena are given hereunder.

Reverberation time is the most important parameter for assessing sound performance of the environment under review and results indicate performance in line with project requirements.

Figure 11 compares project reverberation time versus field measurements. Low values are noted over the entire frequency range referred to volume. Measurements were lower than expected under 250 Hz; so outstanding low frequency reverberation control had been achieved, usually more critical in similar environments, Limited reverberation excess versus simulated levels in the 500 to 2000Hz range is tied to complex difficult to simulate and forecast acoustic phenomena close to empty grandstand seats.

It should however be underscored that the arena is to operate both completely and partly occupied, so seated person sound absorption will cause a single tone trend featuring decreasing reverberation time above 500Hz, thereby aligning real to expected project times.

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Figure 11 – empty chamber reverberation measurement time as per project

FINAL REMARKS ON PASSIVE ACOUSTICS

Reverberation time is close to optimum for future arena use too for speech and music tone and dynamic features. Speech intelligibility is outstanding thanks to the electro-acoustic sound amplification system designed ad hoc that directs sound energy nearly exclusively to the area involved.

The reverberation time obtained also favours proper sound field distribution to the various seating areas; sound is uniform in terms of wide band sound pressure and spectrum composition with no environmental colouring.

Roof sound absorption also minimises technological plant operation-induced background noise.