Project no. 516417

PRO-STONE

Eco-Efficient and High Productive Stone Processing by Multifunctional Materials

Collective research Project

Final activity report

Period covered: 1st July 2005 / 30th June 2008

Date of preparation: 01/07/2008

Start date of project: 01/07/2005

Duration: 36 Months

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Project coordinator organisation name: D'Appolonia

first revision

TABLE OF CONTENT

1 Executive Summary

Figures on world stone trade show that the market share of the EU countries has been decreasing over the last few years in favour of relatively new Far East and Southern American countries. The main reasons for this is that the sector has not made any significant technological progress and operations are faced by low productivity and efficiency, fluctuation in the quality, huge quantities of waste, high energy consumption and critical safety for the workers. The development of environmentally friendlier technologies is indeed an issue, considering that stone is a non-renewable resource. Furthermore the European equipment manufacturers have been made more aware of safety and health (noise, dust, etc.) of the operators through recent stringent regulations that requires for alternative technologies. To address these issues scattered attempts have been registered in Europe to apply knowledge-based multifunctional materials in stone tools and equipment. The most promising are based on the application of Shape Memory Alloys (SMA). Several concepts have been developed by our Core Group SMEs based on this novel material. However, the available results show that macro-scale SMA elements have a lower level of reliability and performance reproducibility with respect to micro-scale SMA devices so far applied in the medical sector. The project aims at creating new knowledge in the area of SMA technology and integrates it in a knowledge management infrastructure to facilitate and support design and validation of new machinery concepts by the large and scattered European community of stone SMEs. It also aims at grouping a large number of European IAGs leaded by the European Federation of Stone Industries with the major goal of solving specific needs, improving the technological status of the stone SMEs and transform this rather traditional and regionalised Sector into a modern, competitive and high added value industry.

The partners involved represent a complementary consortium spread along the added value chain (Table 1). The project consortium, together with its wider industrial constituency, brings together organisations from 10 different European countries.

Table 1: Overview of the Consortium

Partner Profile	**Partner no.**	**Participant name**	**Participant short name**	**Country**
Engineering company providing contract research services	1	D'Appolonia S.p.A.	DAPP	I
EuroRoc is the European stone federation	2	European and International Federation of Natural Stone Industries	EUROROC	B
German Stone Federation	3	ZDN	ZDN	D
Industrial association of the Massa-Carrara area, main stone district in Italy	4	Associazione Industriali di Massa Carrara	ASSOINDUSTRIALI	I
Portuguese Stone Federation	5	Associação Portuguesa dos Industriais de Mármores e Ramos Afins	ASSIMAGRA	P
Bulgarian Stone Federation	6	Bulgaro-Italiana Targoska,Zemedelska e Industrialna Kamara	BIK	BG
Greek Stone Federation	7	Association of Marble Companies of Attica	GMA	EL
Italian stone machine producer	8	Ditta Ripamonti Gianni Sas	RIPAMONTI	I
Leading developer and supplier of drilling equipment	9	Mincon LTD	MINCON	IR
Machine developer and supplier for block slabbing	10	Tesimag S.r.l.	TESIMAG	I
Stone sector manufacturing and tools supplier	11	Sodex ood Ltd	SODEX	BG
Company manufacturing a complete line of marble and granite products in Bulgaria	12	TECHMI ood	TECHMI	BG
Stone processing company of both calcareous and siliceous stone blocks	13	Granitos Maceira SA	MACEIRA	P
Stone processing company of both calcareous and siliceous stone blocks	14	Grupo GALRÃO SA	GALRAO	P
Stone extraction company with quarries in Portugal	15	MASERC - Mármores Sérgio Coelho, Lda	MASERC	P
SME involved in Stone Granite sector in Cologne	16	Schwieren Stein Cologne Granit- und Grabsteinwerkstätten	SCHWIEREN	D

Table 1: Overview of the Consortium
(Continuation)

Partner Profile	**Partner no.**	**Participant name**	**Participant short name**	**Country**
Vertical SME with own quarries and processing workshops	17	Zeidler&Wimmel, Steinbruch- und Steinmetzbetriebe, GmbH & Co.	Z&W	D
Stone processing company of both calcareous and siliceous stone blocks	18	Abra Tomasz Czekaj	ABRA	PL
Granite and marble processing SME with plants in the Tuscany area	19	ECSEL S.p.A.	ECSEL	I
Stone quarry and processing SME of marble blocks	20	Megamarm LTD	MEGAMARM	EL
Stone extraction company with quarries in Greece	21	Laskaridis	LASKA	EL
Service Center stone district, owning a large laboratory for supporting machine manufacturers on testing and performance evaluation	22	Sviluppo Italia Toscana	SVIT	I
Largest school of engineering, science and technology in Portugal	23	Instituto Superior Técnico	IST	P
The Institute of Physics of the Academy of Sciences	24	Institute of Physics, Academy of Sciences of the Czech Republic	IOP	CZ
NTUA is the largest Greek University	25	National Technical University of Athens	NTUA	EL
Company designing and manufacturing diamond and CBN tools.	26	Pomdi Herramientas de Diamante	POMDI	ES
Company supplier and installer of natural stone products.	27	G. Chrissafakis S.A	CHRISSAFAKIS	EL

2 Project objectives and achievements during the reporting period

2.1 General Project Objectives

The overall technological objectives of the PRO-STONE project are:

- to fully characterize at least ten ornamental stone types – such as granite, gabbro, quartzite, marble, and limestone – to correlate parameters as stone macro hardness, stone Young's modulus, fracture toughness, critical stress intensity factor, fracture strength, statistical distribution and stone abrasiveness to equipment parameters such as the generated forces, the energy consumption and the tool wear ratio as well as to model the quasi-static propagation of cracks and fractures in stone blocks and the stone-tool interaction under dynamic processing conditions;
- to scientifically characterize the fatigue behaviour (fatigue strength and cycles) of four SMA families like Ni-Ti, Ni-Ti-Cu, Cu-Zn-Al, and Ni-Mn-Ga (this latter ferromagnetic, FSMAs) alloys, and at least ten different geometries as well as different representative dimensions thereof, subject to multiaxial monotonic or cyclic loading as well as large forces as the ones experienced in bulky applications like stone extraction and processing in order to be able to guarantee repeatable and reliable performances as well as a predictable lifetime for multifunctional components to be widely integrated into novel high performance machinery and tools;
- to extensively analyse and characterize ten different joint designs and methods and other connections and bonds both in the case SMA-SMA and SMA-stainless steel connections and their mechanical and fatigue behaviour;
- to develop numerical models able to describe the large forces and displacements that can be generated due to the shape memory effect of the selected representative SMA types and SMA component geometries as well as complex arrays of elementary geometries to be used as actuators on the basis of the performed testing campaigns;
- to model the superelastic behaviour in large diameter wires or other mechanical components subject to cyclic loading over at least 1000 cycles for Ni-Ti, Ni-Ti-Cu and Cu-Zn-Al families, by integrating constitutive models able to simulate the strain energy absorption mechanism;
- to analyse different types of actuation mechanisms which are case by case applicable to different SMA types and geometries in order to fully understand and characterize the actuation-related non-homogeneous deformations that occur in specimens of different geometries and dimensions, thus to model deformations and find out relations that allow optimizing actuation forces or displacements versus applied actuation energy and modes.

Performance degradation phenomena will be investigated as well in order to guarantee the proper reliability of the SMA-based component. Stress sensing properties will be as well characterised in order to evaluate the potential of developing integrated SMA-based sensor-actuator smart components or self-diagnostic features to the machines;

- to develop an e-learning module dealing with SMAs knowledge, basic principles and applications to stimulate the take up of knowledge on SMAs by SMEs. The e-learning module will be developed with the objective to transfer basic principles of SMA technology as well as to give examples of applications in the stone sector to SMEs, so as to stimulate the generation of new SMA-based ideas and applications within the stone processing industry. For this purpose, the e-learning module will avail itself of an interactive e-training environment to identify the user knowledge needs and lead him to the different training modules;
- to develop a Design Support System to assist SMEs in the development and validation of new SMA-based concepts. The Design Support System will be made available through a Knowledge Web Platform and will guide users in the validation and preliminary design of SMA-based concepts, through the use of the knowledge available in different knowledge based repositories, and specifically the Machines Knowledge Based Repository, the SMAs Knowledge Based Repository, the Stones Knowledge Based Repository, as well as through the use of numerical models. Repositories will contain technical data on SMA materials/components, stone mechanics and stone quarrying and processing machinery/tools to be made available to the user through guided and focused queries to the Design Support System.

2.2 Project achievements

During the project the following tasks have been performed:

- Task 1.1: Critical review of stone tools and machines (end of activities planned for December 2006);
- Task 1.2: Analysis of machinery mechanics and working principles (end of activities planned for December 2006);
- Task 1.3: Identification of potential application opportunities (end of activities planned for December 2006);
- Task 2.1: Definition of material characteristics and evaluation of stone mechanical properties and fracture behaviour (end of activities planned for August 2006);

- Task 2.2: Modelling of quasi-static propagation of cracks and fractures in stone blocks (end of activities planned for August 2006);
- Task 2.3: Evaluation of stone-tool interaction under dynamic processing conditions (end of activities planned for April 2006);
- Task 3.1: SMA technical literature review and setting up of a technical information system (concluded on schedule);
- Task 3.2: Definition of representative testing procedures (concluded on schedule);
- Task 3.3: Characterisation and modelling of generated forces and displacements from SMA actuators (end of activities planned for June 2006);
- Task 3.4: Identification and characterisation of SMA joints (end of activities planed for June 2006 - sent August 2007);
- Task 3.5: Identification of applicable actuation strategies (end of activities planned for June 2006);
- Task 4.1: Design and setup of Knowledge Web Portal architecture, common services and application maintenance (end of activities planned for June 2008);
- Task 4.2: Development of e-training for demonstration and training (end of activities planned for December 2007);
- Task 4.3: Development and optimisation of the Design Support System (end of activities planned for December 2007);
- Task 5.1: Prototype of pilot demonstrators (end of activities planned for December 2007);
- Task 5.2: Testing of pilot demonstrators and validation of the Design Support System (end of activities planned for December 2007);
- Task 6.1: Protection of IPR (end of activities planned for June 2008);
- Task 6.2: Exploitation and Dissemination (end of activities planned for June 2008);
- Task 7.1: Training (end of activities planned for June 2008);
- Task 8.1: consortium management (end of activities planned for June 2008).

Deliverables have been prepared and sent in line with the time schedule of the project. The exception was the deliverable D20 “Characterisation of SMA joints”, which has been delivered in August 2007 instead of planned date - June 2007. The delay did not represent criticalities from the technical point of view. All the experimental activities concerning the SMA joints have been carried out.
The deliverables submitted during the 36 months of the project are listed below:

- D1: Early IPR Agreement (DAPP, M3);
- D2: Innovation tracking system (DAPP, M6);
- D3: First version of the PRO-STONE Homepage (EUROROC, M6);
- D4: PRO-STONE Dissemination Plan (EUROROC, M6);
- D5: Project presentation (EUROROC, M6);
- D6: Progress report at month 6 (DAPP, M6);
- D7: Technical SMA information system (DAPP, M10);
- D8: Testing equipment (NTUA, M10);
- D9: Progress Report at month 12 (DAPP, M12);
- D10: Design and setup of Knowledge Web Portal architecture (DAPP, M12).
- D11: Characterisation of stones mechanical properties (SVIT, M14);
- D12: Models for quasi-static propagation of cracks and fractures in stone blocks (DAPP, M14);
- D13: Critical review of machinery and equipment and identification of representative geometries (DAPP, M18);
- D14: Identification of potential application opportunities (IOP, M18);
- D15: Preliminary version of Plan for Use and Dissemination of Knowledge (DAPP, M18);
- D16: Mid-Term Assessment Report at month 18 (DAPP, M18);
- D17: Development of an e-training section for demonstration and training (DAPP, M18);
- D18: First version of Training Plan (SVIT, M21);
- D19: Evaluation of stone-tool interaction under dynamic (IST, M22);
- D20: Characterisation of SMA joints (NTUA, M24 – sent M26);
- D21: Characterisation of forces and displacement from SMA actuators (IOP, M24);
- D22: Characterisation of actuation strategies (DAPP, M24);
- D23: Characterisation and modelling of fatigue behaviour of superelastic SMA components (IOP, M24);
- D24: Progress Report at Month 24 (DAPP, M24);
- D25: Development of the Design Support System through the integration of models (DAPP, M30);
- D26: Prototyping of pilot demonstrators and validation testing (IOP, M30);
- D27: Progress Report at month 30 (DAPP, M30);

- D28: Knowledge Web Portal: common services and application maintenance (DAPP, M36);
- D29: Final version of Plan for Use and Dissemination of Knowledge (DAPP, M36);
- D30: PRO-STONE Dissemination Report (EUROROC, M36);
- D31: Training Reports based on feedbacks of the SME Core Group members (SVIT, M36);
- D32: Final Report at month 36 (DAPP, M36).

- The 12-month-meeting was held on 4th July 2006 in Lisbon (Portugal) at the IST premises.
- The 24-month-meeting was held on 8th June 2007 in Nuremberg (Germany) at the Stone+Tech International Fair.
- The 30-month-meeting was held on 18th January 2008 in Prague (Czech Republic). The 36-month final meeting was held on 28th May 2008 in Carrara (Italy).

2.3 Problems encountered and corrective actions

No problems have arisen during the 36 months of the project: the scheduled activities were efficiently performed on time by all the partners involved. The following milestones have been successfully reached along the whole reporting period respectively at Months 6 (M1), 12 (M2), 14 (M3), 18 (M4), 24 (M5), 30 (M6), 36 (M7) and 36 (M8):

- M1 – Preliminary Identification of Potential Application Opportunities: such Milestone can be considered successfully achieved based on the fact that the consortium at Month 6 has identified 11 potential applications related to the Stone sector in which the use of SMA is foreseen;
- M2 – First release of the Knowledge Web Portal: this Milestone can be considered successfully achieved since a first version of the Knowledge Web Portal is now online. In particular, the architecture of the platform has been designed and different functionalities and applications have been structured including easy querying and search facilities into the Machine Knowledge Based Repository, the SMAs Knowledge Based Repository and Stones Knowledge Based repository.
- M3 – Ornamental stones characterisation and study of stone-tool interaction and cracks propagation: such Milestone can be considered successfully achieved based on the fact that a reliable model simulating the quasi-static cracks propagation as well as the fracture in stone blocks caused by the stone extracting or by the stone processing equipment. The comparison

with experimental data obtained trough extensive characterisation activities of 37 type of ornamental stone showed the reliability of the model developed;

- M4 – Mid-Term Assessment Meeting: this Milestone can be considered successfully achieved since the milestones have been assessed against the progress of the project with respect to schedule and the achieved partial result described by the partner have been considered compliant with the foreseen activities. In detail the progress of the project has been assessed with respect to the achievement of milestones M1, M2 and M3 and related deliverables.
- M5 – Characterisation of SMA elements with respect to fatigue behaviour, generated forces and displacements and analysis of applicable joining methods and actuation strategies: this Milestone has been successfully achieved on the fact that since a) the guidelines for joining and other coupling procedures applicable to SMA-SMA and SMA-stainless steel elements, including full characterisation of each applicable method have been performed; b) the guidelines for optimal actuation strategies for different SMA element geometries, including full characterisation of actuation-related non-homogeneous deformations have been accomplished; c) the models for describing the forces/displacements generated by some SMA representative components/actuators (at least 10 different geometries and different representative dimensions) and correlation with experimental results have been completed; d) the models for describing the superelastic behaviour of large diameter wires or other mechanical components subject to cyclic loading and correlation with experimental results have been realized
- M6 – Design Support System; such Milestone can be considered successfully achieved based on fact of release of the Design Support System on the Knowledge Web Portal, which integrates all the developed models and based on the Knowledge Based Repositories. The Design Support System has been developed taking into account the need to spread the SMA knowledge in an intuitive way, highlighting the several possibilities offered by these materials. It has been conceived so as to educate the user in what concerns working principles and application potential of those materials, subsequently to stimulate and support the user in the conception of new ideas based on the exploitation of Shape Memory Alloys. The simple structure and easy to use approach of the tool allows unskilled users to exploit the potentialities of the Design Support Tool.
- M7 – Successful industrial validation and Plan for Use and Dissemination of Knowledge: this Milestone can be considered successfully achieved since the milestones have been assessed

the industrial validation of the project results as well as against the release of the final version of the Plan for Use and Dissemination of Knowledge.

- M8 – Final Assessment Meeting: this Milestone has been successfully assessed against the achievement of all the proposed objectives, which will have to be described by the Partners within the Final Progress Report. In particular, the progress of the project will be assessed with respect to the achievement of milestones M1, M2, M3, M4, M5, M6 and M7 and related deliverables.

3 Work package progress of the period

The activities performed in the 36 months, as scheduled by the project plan, are relative to WP1 – Critical analysis of stone machinery, equipments and opportunities; WP2 – Stone characterisation, study of fracture behaviour and stone-tool interaction; WP3 – SMA components: joining and actuation strategies; WP4 – Development of the Knowledge Web Portal and Design Support System; WP5 – Validation of the Design Support System; WP6 – Exploitation and Dissemination Activities; WP7 – Training Activities; WP8 Consortium Management.

In the following paragraphs the activities performed in the project are reported as far as activities related to tasks 1.1, 1.2 and 1.3 of WP 1, to tasks 2.1, 2.2, and 2.3 of WP 2, to tasks 3.1, 3.2, 3.3, 3.4, and 3.5 of WP 3 to task 4.1, 4.2, 4.3 of WP4, to task 5.1, 5.2 of WP5, to tasks 6.1 and 6.2 of WP 6, to task 7.1 of WP7 and to task 8.1 of WP 8 are concerned.

3.1 WP 1: Critical analysis of stone machinery, equipments and opportunities

Objectives: Critical review of machines and tools for stone quarrying and processing, analysis of the working principles of the machines/tools and identification of representative and recurrent mechanical component geometries and identification of potential application opportunities.

3.1.1 Task 1.1 Critical review of stone tools and machines

Starting Date: July 2005
Ending Date: December 2006

Aim of this task was to perform a critical review of the stone tools and equipment used to extract stone blocks from quarries and to further process them. In particular the objective of such activities has been to provide IAGs with a comprehensive analysis of the machines/tools in terms of working principles, main applications, advantages and disadvantages. In order to reach the above mentioned objective a questionnaire has been prepared by DAPP to be completed by the SMEs and the end-users. The questionnaire required information concerning description of the machines, main characteristics, applications, advantages and disadvantages by asking also the SMEs for an opinion on how to improve the performance of the machines.

Moreover, the technical questionnaire was translated in various languages apart from the English version in order to help the entrepreneurs in filling the required data. DAPP, NTUA, SVIT, EUROROC and IST met the SMEs partners and other stone SMEs in order to collect data related to traditional quarrying and processing tools based on technical datasheets questionnaires. In particular, several visits to the core group SMEs premises have been carried out. The following picture (Figure 1), taken during such technical meetings, provides an overview of the machinery taken into account.

Figure 1: Granite quarry (MACEIRA). From the photo it is possible to observe the variety of difficulties arising from the extraction of a granite block

As a result of this data acquisition campaign launched by the RTD performers, the SMEs core group and the IAGs of the project proactively contributed and an overall number of 44 questionnaires have been received.

In parallel, DAPP, IST and NTUA have performed a detailed review of technical documentation (i.e. technical brochures of equipment, papers on scientific and sectoral press and proceedings) related to the subject of interest, together with the analysis of the patents for the most representative tools.

Taking into account both the results of such review and the outputs from the data and information acquired through the questionnaires, technical datasheets have been prepared on more than 37 different tools and equipment in which, apart from a brief description of the working principles, advantages and disadvantages and technical characteristics are reported. This has been the base for the content of the Machines Knowledge Repository, whose architecture has been developed in Task 4.1 described in the following paragraphs.

After that this task has been continuously discussed in several bilateral meetings where specific aspects were discussed and detailed by IST, SVIT and each of the partners involved. Various technical visits have been made to the plants, in order to detail accurately the systems where applications of SMA are indeed very helpful.

The data sheets have been duly implemented. The sheet includes a brief description of the tool functioning, photos highlighting the machine in working conditions, the most important parameters needed to be considered to evaluate the cost-effectiveness and a exhaustive list of advantages and drawbacks.

Thanks to that machine repository the user will be prepared for the next steps of the design support tool useful for carrying out all the possible improving application of the SMA material in the stone sector.

The conclusion about the application of the technical sheets leads to the definition of 3 main groups of applications where tools and/or machines lack of efficiency:

1. Quarrying – namely in the extractive side of the work, especially applied to dimensional stone.
2. Slabbing – in the gangsaw systems there are different problems when discussing the granite and the marble slabbing.
3. Circular sawing (large discs) – in marble, but mainly in granite circular sawing, the high level of forces attained when cutting with large discs have constrained the use of thinner steel rims.

3.1.2 Task 1.2 Analysis of machinery mechanics and working principles

Starting Date: September 2005

Ending Date: December 2006

Aim of this task was to analyze the mechanics and detailed working principles of the machines which are used in Stone quarrying and processing. The analysis of the technical sheets was based on the following principles:

- Identify on each plant the critical family of equipment / component that does not have yet an optimised performance;
- Use the work to identify possible routes of action to optimise the equipment / component, by introducing either a new component or a new procedure. The conclusions have been directly related with the discussion made around the use of SMA components.

As anticipated, DAPP collected 44 completed technical sheets from the partners. Based on such inputs and on the review of available literature documentation a study in order to identify the technical needs of the main machines was carried out. The data coming from the partner's questionnaires has been inserted into a database: the information can be easily managed and retrieved from the database thanks to simple queries. The technical disadvantages and problems outlined by the questionnaires have been clustered in families.

Through the analysis several geometries of components and sub-components have been identified. From the analysis made in the technical sheets it has been possible to outline that there are several equipments / tools that need further developments.

The data collected for the review of stone tools and machines have been continuously updated. NTUA, under the cooperation of Greek SMEs and associations, has revised the detailed study in machinery mechanics and especially: in quarrying, down the hole drilling, in processing, frame/wire and sawing polishing.

The analyses of the machinery mechanics and working principles of the machines which operate in quarrying, cutting and processing lines have been carried out according with the following plot:

1. SMA geometries selection
2. Functional decomposition of machines
3. Identification of components to replace the original geometries

The need of such kind of analysis mainly grew from the SMEs concerns about machines disadvantages that are: low productivity, cost of the machines, vibrations and capability of cut only limited sizes of blocks. Tools suffer high costs, and frequent breakages; the sintered diamond contained in the tools gets easily damaged. The main disadvantage related to quality is that often the cuts are not straight due to machine deviations. Some environmental disadvantages are the need of water for cooling, high energy consumption and noise. Some of the main disadvantages related to operators are: costs due to machine maintenance, difficult manual set up, problems to adjust the cutting speed.

The analysis of machinery mechanics and working principles was a study that had mainly two results: functionally decompose the quarry and processing machines in order in order to find their main components/functions, identify the components that can be successfully replaced by a SMA element. The SMA geometries considered were: wire, tube, plate, cylinder, linear spring, torsion spring and cube. The analysis reported represents a valuable source for stone machines designers interested in innovating existing machines or designing new one.

3.1.3 Task 1.3 Identification of potential application opportunities

Starting Date: September 2005
Ending Date: December 2006

Based on the analysis of the outputs from Tasks 1.1 and 1.2 and in particular on the assessment of the technological needs of the SMEs involved in the Stone quarrying and processing sectors, the identification of potential application opportunities for SMA components into Stone equipments and tools the partners has been carried out. All partners have been heavily involved in such activity: RTD contributed to the work by sharing their scientific knowledge with the consortium, IAGs and SMEs contributed with their on-field experience and strong knowledge on currently used equipment and machinery. In order to carry out such task in the most appropriate way, it was decided that first a training session on SMA was necessary, by anticipating part of the activities of Task 7.1 as described in the following paragraphs: this was due to the fact that in order to involve SMEs and IAGs in this "problem solving" activity, it was necessary for them to understand in detail what are the working principles and capabilities of SMA. The tutorial was prepared by DAPP and made available to all partners. The following table provides an overview of the applications selected (Table 2).

Table 2: Overview of the selected potential application ideas

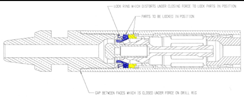
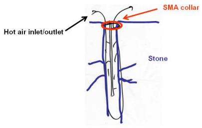
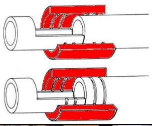
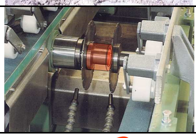
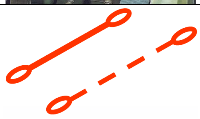
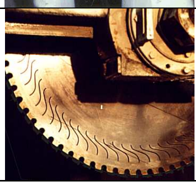
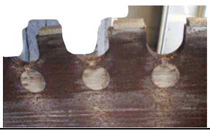
Idea N°	Image	Description
01		**DTH hammers ring** Replace steel lock rig with SMA lock ring **Advantages**: No need to torque the hammer up prior to use **Drawbacks**: We need to do assembly at low temperature
02		**Air splitting collar** Replace lock rig with SMA lock ring **Advantages**: Decrease air losses **Drawbacks**: We need to do assembly at low temperature
03		**Down the hole hammer grip for poles** Join poles with SMA collar **Advantages**: Firm & easy coupling **Drawbacks**: An hot/cold source is necessary on field (fire, dry ice)
04		**Chain saw : SMA belt** Create a SMA belt for chain saw **Advantages**: The belt is stronger than plastic **Drawbacks**: The fixing of the diamond blades and the working speed need to be investigated
05		**Cutting discs spacer** Actively constrain the disks distance using SMA elements. **Advantages**: Increase cutting disks stiffness, improve cut accuracy **Drawbacks**: The size of the SMA elements may reduces the cutting depth of the instrument
06		**SMA tendons** SMA tensioning system: try to keep constant the tension of the cutting blade, during the cut, using the SMA super elastic effect **Advantages**: Simplify the cutting tools tensioning system **Drawbacks**: The elongation of the tendons is limited to a few %
07		**SMA hydraulic cushion for bank turning over** b) Replace the cushion with a device actuated by SMA or b) Create a cushion with SMA plates (superelastic effect) **Advantages**: The same cushion can be used several times **Drawbacks**: The necessary cushion deformation may limit the number of cycles
08		**SMA inner foil in cutting disk** Lower vibrations and noise adding SMA inner foils to steel cutting disks: normally inner foils are made by copper or fiber glass **Advantages**: Reduce vibrations. Simplify the cutting tools design **Drawbacks**: SMA strength characteristics are worse than steel. Probably it is not possible, by heating, to recover the original shape of the SMA inserts
09		**SMA leaf spring** Use SMA to create a leaf spring of the filter press **Advantages**: Reduce maintenance **Drawbacks**: SMA and steel spring have different characteristics
10		**Drill holding system** Superelastic SMA system that can better absorb the hammering percussion on the tool **Advantages**: Reduces the risk of failure **Drawbacks**: High mechanical resistance is required. Design can be complex
11		**Spring for gangsaw tensioning system** Coil systems with high energy absorption and high elasticity **Advantages**: Gives continuous contact to the blades. Less wear and breakages **Drawbacks**: A custom spring needs to be designed and tested
12		**SMA inserts in giant blade** Increase the deformation of the giant blade by introducing SMA elements in the metallic rim **Advantages**: Reduces the risk of plastic deformation **Drawbacks**: The joint between SMA and metal may be difficult: if SMA is joined by welding, its characteristics result altered

Table 2: Overview of the selected potential application ideas (Continuation)

Idea N°	Image	Description
13		**Stones polishing pressure control** Improve the pressure system used to press and sustain the rotating heads that hold the polishing tools **Advantages**: A good pressure stabilization allows to decrease the number of polishing stages **Drawbacks**: The design and integration of the SMA mechanism could be not trivial

For each of the application ideas identified, the RTD performers and especially IOP and DAPP have performed a pre-feasibility assessment in order to evaluate if the working conditions for each application idea were compliant with the intrinsic properties and characteristics of SMA.
Based on this wide scenario of different application opportunities, a further selection has been made by the core group SMEs and IAGs. Finally, three applications have been selected: ‘blade holder’, ‘SMA ‘giant disc’ and ‘air splitting collar’.

The scope of this task was to demonstrate the effective applicability of SMAs in the Stone Sector, this is the reason why three potential demonstrators were identified in which at least one component of the tool/machine is made of shape memory alloy.

3.2 WP 2: Stone characterisation, study of fracture behaviour and stone-tool interaction

Objectives: Extensive characterisation of ornamental stones to assess the material's characteristics that allow the evaluation of stone mechanical properties and fracture behaviour, evaluation and modelling of quasi-static propagation of cracks in stone blocks (fracture process) and evaluation and modelling of stone-tool interactions under dynamic processing conditions.

3.2.1 Task 2.1 Definition of material characteristics and evaluation of stone mechanical properties and fracture behaviour

Starting Date: November 2005

Ending Date: August 2006

Within Task 2.1, the activities have been carried out with a large involvement of the SME Core Group and IAGs that have, among other actions:

- Widely informed and explained about the critical aspects that need to be considered for some stones when performing specific transformation stages;
- Informed about the properties that were already measured in the stones that are processed in their companies;
- Supplied the great number of the test specimens, including the use of block materials to cut stones in different directions so that anisotropic elastic properties could be evaluated. The specimens have also been supplied with different final finishing so that fracture analysis could be evaluated in terms of intrinsic and extrinsic defects.

Within the framework of this task, the consortium initially focused on the analysis and selection of the most representative stones to be taken into account. Secondly, a testing campaign to determine the following parameters has been carried out:

- density porosity and water absorption;
- hardness;
- elastic properties – Young's Modulus;
- Fracture toughness;
- Mechanical strength;

- Stone relative abrasiveness.

In the work proposed in Task 2.1 the range of stones to be tested must represent the type of processes that need to be analyzed.

In summary, the range of stones selected necessarily represent the most common applications, but with emphasis to those stones where certain aspects (extraction and transformation stages) need to be improved, either by improving tools, equipments or even specific processing routes. In general, and despite of their denomination or location, the following kinds of stones were found to be relevant for being analyzed.

The work has conducted to a series of conclusions concerning the selection of the stones. In the end, several types of stones (Table 3) have been selected to cover a significant number of cases.

Table 3: Selected stones

	Metamorphic	**Sedimentary**	**Igneous**
Types of stones	Marble Slate	Limestone Sandstone	Granite
Decision	Estremoz (P), Ruivina (P), Carrara (I), Thassos (GR), Slate (P)	Moleanos (P), Crema Marfil (E) Mucharz (PL), Eichenbühler (D)	SPI (P), Robrato (P), Rosa Monforte (P), Porrino (E), Impala (SA)

Note: D – Germany E – Spain GR – Greece I – Italy P – Portugal PL – Poland SA – South Africa

Among all types of ornamental stones, marble and limestone are the most used materials for different types of applications.

Along the experimental work, several characteristics of each stone will be used for being applied either in performing Task 2.2 and/or Task 2.3. Therefore, some of the stones described in the previous table can be replaced by others that allow a more direct comparison with the application that will be analyzed.

3.2.2 Task 2.2 Modelling of quasi-static propagation of cracks and fractures in stone blocks

Starting Date: March 2006

Ending Date: August 2006

Aim of this task has been to predict, by numerical simulations, the mechanical behavior of different types of stones under different loading conditions. The numerical modeling of the quasi-static propagation of cracks inside the block has been performed using software suitable for the fracture analysis (FRActure ANalysis Code - FRANC2D).

Figure 2: Squaring off a bank of marble

The operations by which a bank is "squared off" to have commercial blocks are performed using drilling machines and splitting devices. The first operation was performed by using compressed air, hydraulic, manual or automatic drilling (Figure 2).

In this framework, the prediction of the phenomena of cracks propagation appears particularly relevant and suitable numerical models have been developed for comparing the mechanical behaviour of several types of stones.

The CAD model of the stone is shown in Figure 3 and the material data used for the numerical analysis have been provided by IST. The strong co-operation with the SMEs involved in the PRO-STONE project allowed defining the most suitable case studies in terms of block geometry, stone material, boundaries and loading conditions.

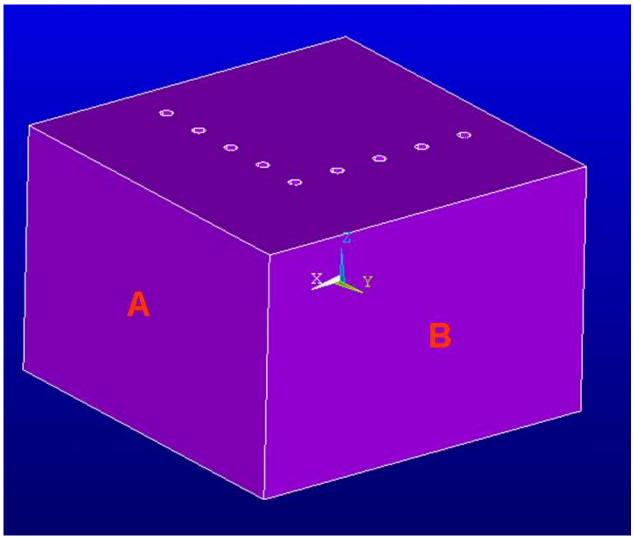


Figure 3: CAD Model of the Stone Block

As anticipated, the software used for the numerical analyses is the FRActure ANalysy Code FRANC2D, a two dimensional, finite element based program suitable for simulating the curvilinear crack propagation in the structures. The stone geometry and the initial mesh generation have been

performed using the software CASCA, a pre-processor of FRANC2D developed by the Cornell University.
Two fracture mechanics models have been considered for the quasi-static crack propagation.

The large experience of the SMEs in stone sector has allowed identifying representative types of stones: considering the linear elastic materials, the following materials have been hence considered: Rosa Aurora (marble), Impala (granite), Cinza Pinhel (granite) and SPI (granite).
The main material properties (considering a linear elastic orthotropic model) have been provided by IST. The Fracture Analysis started from the evaluation of the stress and deformation calculated in the stone model without initial cracks.

After introducing the initial cracks to the structure and after performing a new stress analysis , the crack propagation is performed automatically.
The history of the stress intensity factors over the previous steps of propagation are provided by the software.

3.2.3 Task 2.3 Evaluation of stone-tool interaction under dynamic processing conditions

Starting Date: May 2006
Ending Date: April 2007

Within the framework of such activity the objective is to evaluate the stone-tool interaction under processing conditions namely drilling, sawing and grinding. The inputs that have been considered are the parameters that have been evaluated in Task 2.1 such as stone abrasiveness, the stone macro hardness, the stone fracture toughness and the stone fracture strength statistical distribution. Moreover, the analysis which has been performed in Task 2.2 is taken into account.
The objective of this task was to validate the stone-tool interaction under dynamic processing conditions based on the lateral crack wear mechanism approach.
Therefore, various test using different cutting tools will be performed at a laboratory scale by IST, with the support of SVIT, SMEs Core Group and IAGs. The results have been related to the mechanical properties and the relationship has been validated by performing an extensive testing campaign and evaluating the results.

As a first step and in order to understand a single process, an analysis regarding the influencing parameters and their effect on the process has been performed. The relevant parameters have been divided into three groups:

- Input Parameters – including: the type of stone involved and its most relevant properties, such as hardness, strength; the machinery and inherent parameters, power available, vibration behaviour, etc; the type of tool, quality of abrasive material, content of diamonds, bonding material and its properties; the process parameters, such as cutting speed, infeed velocity, etc.; among others.
- Processing Parameters – including: the chipping thickness which is not always controlled when using standard technologies; the resulting temperature of the process; the cutting energy; the process resulting forces, which will be decisive in the tool wear behaviour; among others normally less relevant.
- Output Parameters – including: accuracy on dimensions of stone products; surface quality, in terms of roughness, gloss, amount of defects caused by the process, etc.; overall energy consumption; amount of waste material; tool wear behaviour, which is normally associated to its lifetime; performance, which can be measured in terms of, for example, productivity.

In this task, initiated in month 11, several issues have been investigated in detailed.

During the last months IST concentred its effort on the evaluation of stone-tool interaction following the as a guidelines the need to the understanding of what is behind the performance of any process dealing with cutting stones. The plot followed for the achievement of this result has been:

1. understand the cut process
2. look at the mechanism
3. allowing to foresee the problems
4. contributing to improve the materials
5. increase the performance

The conclusions concerning outcome of this work in relation to the process “quality” system are basically:

- Definition of quantitative parameters (DHC and BWR) that depend on both tool and rock dependencies but without considering both of them as parameters that control the operation;
- Validation of this methodology for various applications;
- Understanding of the influences of the working conditions set in different applications;
- Indication of optimum parameters for each type of application.

On the other hand, the conclusions withdrawn from the mechanisms point of view are:

- Validation of Evans and Marshall approach to explain the wear suffered by the stone;
- Understanding how the forces interact with the tools and cause damage depending on the type of stone used (different mechanical properties studied in Task 2.1);
- Suggestion of a possible wear model to explain the wear caused in the matrices that support the diamond, depending on the type of stone that is being used. This erosive wear model is extended to other materials rather than stones;
- Interdependencies of lateral crack mechanism and erosive wear on the different applications and explanation of the outputs depending on two basic parameters, resultant force and chip thickness.

Both perspectives have been analysed in detailed during this work and validated through an extensive testing campaign performed in SME industrial partners with the help of POMDI, SVIT and the remaining partners that have contributed to optimise the models used in function of the real industrial results.

3.3 WP 3: SMA components: joining and actuation strategies

Objectives: Setting up of a technical information system on Shape Memory Alloys through an extensive literature review. Definition of representative testing conditions and setup of experimental equipment for SMA components: testing, joining modes characterization and actuation modes testing. Characterisation and modelling of generated forces and displacements for the selected representative SMA component geometries and complex arrays of elementary geometries to be used as actuators. Identification and characterisation of SMA-SMA or SMA-stainless steel joining modes and testing of fatigue failure thereof. Identification of all applicable actuation strategies, testing of actuation modes, characterisation and FE modelling of actuation-related non-homogeneous deformations; identification of SMA strain sensing properties.

Task 3.1 SMA technical literature review and setting up of a technical information system

Start Date: November 2005
Ending Date: April 2006

The Technical SMA Information System has been set up as one of the application supported by the SMA knowledge repository. The Technical SMA Information System is based on an extensive literature review on Shape Memory Alloys, which concerned the analysis of existing SMA applications as an initial step, followed by an extensive analysis of technical data available through technical literature sources as well as technical product data sheets. The information acquired has been structured into a smart web-based information base containing data on properties of four selected Shape Memory Alloy families such as Ni-Ti, Ni-Ti-Cu, Cu-Zn-Al and Ni-Mn-Ga, which are considered as being capable to offer the major potential for application in the stone sector due to their peculiar performances with respect to other SMA families.

Finally, in order to provide SMEs of the stone sector with a valid tool for exploiting the technical information contained in the SMA Knowledge repository, the Technical SMA Information System has been developed as a smart web-based information base supporting different functionalities for inquiry which allow retrieving the technical data in a structured and highly focused way.

After that, the data has been selected, filtered and populated within the information base and further focused reviews have been carried out to be able to fill in missing information to the largest extent.

Compliantly with the procedure set up for the evaluation and validation of the overall PROSTONE Knowledge Web Portal (described in the following paragraph), a collection of feedback has been launched within the consortium in order to assess the real usability of the SMA Technical Information System from the industrial partners involved. Based on the inputs collected, minor modifications and improvements have been carried out.

An exhaustive analysis about the mechanical properties has been carried out using also two Instron testing machine dedicated the 1362 (screw type) and the 8872 (hydraulic) for the thick wires and the Walterbai for the thin wires.

Finally the SMA actuation has been modelled implementing the following models:

- Phenomenological model of SMAs-RLOOP
- FEM implemented model of SMAs-iRLOOP
- Micromechanics model of SMAs

In order to complete the SMA components investigation a characterisation and modelling of fatigue behaviour of superelastic SMA components has been carried out.

Particular attention has been paid to cyclic superelastic deformation in tension and cyclic thermomechanical loadings (Figure 4),

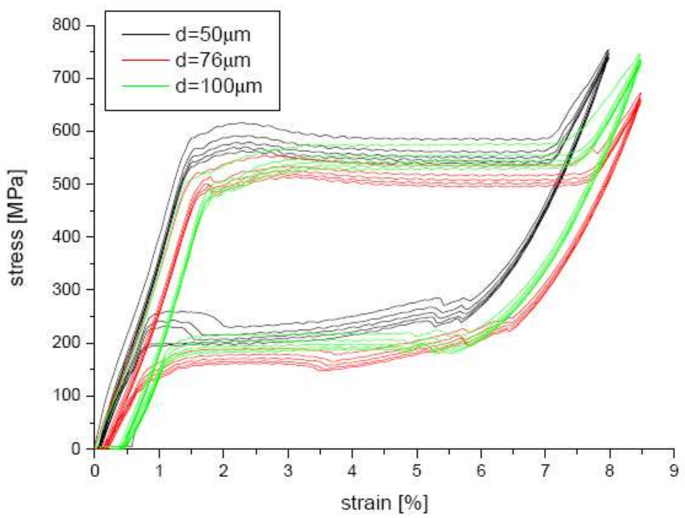


Figure 4 – Superelastic deformation and cyclic thermomechanical loadings

3.3.2 Task 3.2 Definition of representative testing procedures

Start Date: November 2005

Ending Date: April 2006

In order to determine appropriate testing conditions, experiments and procedures for the SMA components, an extensive mathematical modeling of the major quarrying and processing technologies has been included in the deliverable in order to identify the forces applied on the mechanical parts and the cutting tools.

Secondly, the basic processing operations have been considered (sewing, polishing, removal process).

The basic tests were focused on the mechanical properties of SMA and while the extended testing includes more complex tests concerning their electrical, acoustic and optical properties. Also the suitable equipment needed for the tests was listed along with the sample types that will be used.

The basic tests concerning the investigation of the mechanical behaviour of SMA include the following:

- stress-strain test,
- strain-stress test,
- stress-temperature test,
- strain-temperature test.

The extended set included the following tests:

- Electrical resistivity measurements;
- Acoustic properties measurements;
- Calorimetry;
- Optical observations.

3.3.3 Task 3.3 Characterisation and modelling of generated forces and displacements from SMA actuators

Start Date: March 2006

Ending Date: June 2007

In order to optimally characterize the forces and displacements required from SMA elements of various types loaded by various deformation modes in a wide temperature range, IOP has purchased and/or developed and built several dedicated new laboratory equipment, in addition to servo-mechanical and hydraulic INSTRON testing machines already available in the laboratory at the start of the PRO-STONE project. All the equipment was built or purchased using institutional budget, not the PRO-STONE budget.

Second area of activity within Task 3.3 has concerned the early experiments focused on characterization of functional performances of selected SMA elements already available at IOP. Main goal of this work was to find out optimal experimental approach to the systematic SMA testing as well as to find out which kind of SMA elements shall be purchased for the planned wide scale experimental campaign. Additionally another field of activity was related to SMA model developments going along with above mentioned experimentation.

Further activities have been focused on modeling, particularly on the development of:

- Phenomenological algorithm Rloop – numerical implementation in Matlab;
- Crystallographic model of SMA - consideration of R-phase and plasticity;
- Continuum model of SMA – adjustment for tensile springs.

Finally, it should be mentioned that a set of unique in-situ experiments has been carried out using magnetically actuated NiMnGa crystals loaded in compression under magnetic fields using miniature deformation machine.

The technical results have been summarized in the deliverable D21 e D22.

3.3.4 Task 3.4 Identification and characterization of SMA joints

Start Date: March 2006

Ending Date: June 2007

The main aim of this task was to identify and characterize SMA-SMA or SMA-stainless steel joining modes with a focus to the demands of the stone machinery sector, mainly characterized by bulky mechanical components demanded to exert large forces. Activities carried out on this task during the first period consisted thus in an extensive analysis and subsequent evaluation of the techniques already tested for joining SMA to SMA or to stainless steel, which was mainly conducted by DAPP, NTUA and IOP. Moreover, research activities have focused so far investigating joining processes for micro-components to be used mainly in the medical sector. As a result, any joining technique has been largely experimented on macro-components such as required by the stone sector.

From month 13 to month 24 NTUA followed the initial aim of the project that was to perform joints of NiTinol SMAs to AISI316L stainless steel by employing fusion welding processes.

Four different welding methodologies have been investigated:

- Tungsten inert gas welding experiments
- Plasma and micro-plasma arc welding experiments
- Electron beam welding experiments
- Resistance welding experiments

The following test and measuring equipment were used in order to examine the specimens:

- Storage oscilloscope
- Electric current meter
- Distance measuring device

From month 25 to month 26 NTUA performed an extension of activities concerning the SMA joining task. During this period an extensive analysis and characterisation of different joining designs and methods has been performed in the case of SMA-stainless steel connections and their mechanical and fatigue behaviour. Tungsten Inert Gas (TIG), Plasma Arc Welding (PAW), Electron Beam Welding (EBW), and Resistance Welding (RW) are the welding techniques that were used. A great variation of the basic welding parameters was investigated.
The most successful technique resulted the Plasma Arc Welding.

3.3.5 Task 3.5 Identification of applicable actuation strategies

Start Date: March 2006
Ending Date: June 2007

The main aim of this task has been to identify actuation methods applicable to SMA components, again, with a focus to the demands of the stone machinery sector.

Actuation of NiTi SMAs is based on the shape memory effect that this class of materials is capable to exploit. The principle is based on thermoelastic reversible solid state displacive transformations between the austenite phase (parent phase) and martensite phases (daughter phases) in response to thermal energy inputs. Thus, this task aims mainly at reviewing modes of providing thermal energy to SMA macro-components as the ones expected to be integrated in stone processing machinery. As a result, a review of applicable actuation modes has been carried out by DAPP, with the objective to evaluate those actuation modes which are most probable to be successfully applied to machinery design. Again, IAGs and SMEs core group were already preliminarily involved in the evaluation process, based on the expertise they could provide in identifying advantages and drawbacks of each mode identified with respect to the application environment, but their support and valuable expertise will be required in a major instance in a subsequent phase focusing on the final validation of actuation methods towards the end of activities.

Activities carried out included thus the review and identification of actuation modes, and their technical evaluation which have been focused on evaluating, for each of the identified modes, major strengths and weaknesses as well as opportunities and threats with a SWOT analysis approach.

Identification of all applicable actuation strategies was also an essential task.

In order to better understand the actuation principles and, in the same time, to stimulate the creative capacities of the partner of the project a very exhaustive literature analysis has been carried out.

Patents, industrial applications or simple prototypes, in which the SMAs were used, have been scouted.

The three PRO-STONE prototypes have been designed taking into account all the SMA actuation strategies presented, and considering the technical needs related to the stone industry. The three selected SMA prototypes are and their relative actuation strategies are widely described in paragraph 3.5.

3.4 WP 4: Development of the Knowledge Web Portal and Design Support System

Objectives: Design and setup of Knowledge Web Portal architecture and common services, development of an e-training section for demonstration and training aimed at stimulation of SMA applications in stone machinery, construction of the knowledge based repositories and development of the Design Support System through the integration of models.

3.4.1 Task 4.1 Design and setup of Knowledge Web Portal architecture, common services and application maintenance

Start Date: July 2005

Ending Date: June 2008

In order to support the introduction of Shape Memory Alloys for new generation stone machinery and equipment development, the PRO-STONE Knowledge Web Portal has been designed with the aim to provide a full range of services useful to provide users with major understanding of those materials and their functioning principles so as to stimulate the generation of new design concepts, taking advantage of the great potential, which is offered by Shape Memory Alloys, for improving especially more traditional actuation systems such as hydraulic or electro-mechanical actuators applied in traditional machinery.

For this purpose, the PRO-STONE Knowledge Web Portal has been conceived and developed by DAPP based on inputs provided by EUROROC, ZDN, ASSOINDUSTRIA, ASSIMAGRA; BIK, and MGA, to guide the user throughout four main phases: introduction to Shape Memory Alloys and training; deepening of technical information on machinery, on stones, and on Shape Memory Alloys; support to design; and support to protection of ideas.

Subsequently, the PRO-STONE applications were conceived in parallel to the whole architecture of the portal. Applications build in fact onto the repositories, which have been appositely designed in order to structure the domain-specific information to be exploited from the different applications. As a result, the PRO-STONE Knowledge Web Portal is composed as an overall of five knowledge bases (repositories), accessible through the PRO-STONE Website, and supporting four applications.

From month 13 to month 24 the layout of the overall PRO-STONE portal had substantial layout changes. The layout improvements have been performed following the feedback from all the PRO-STONE partners. The previous version of the portal included a wide set of tool difficult to reach.

Portal navigation has been improved replacing three layers of horizontal submenus with a main horizontal text menu and a vertical submenu with icons.

The main sections of the portal are: project information, SMA technical Information, stone repository, machine repository, application repository, crack propagation, IPR Tracking Tool, Design Support System and SMA knowledge repository.

Many changes have been continued from month 25 to month 36 of the duration of the project to obtain its final form. The layout improvements have been succeeded thanks to the feedback and the suggestions from the PRO-STONE partners. Following their leads, portal navigation has been changed and improved.

The content of the all databases is currently maintained: extended and corrected continuously according to the future feedback of the PRO-STONE users.

3.4.2 Task 4.2 Development of e-training for demonstration and training

Start Date: July 2006

Ending Date: June 2008

The training environment has been designed by DAPP in collaboration with SVIT. Inputs on the needs have been suggested by SVIT, the SMEs and IAGs. The development of the e-training for the demonstration and training is grown following three main steps: identification of user needs, collection and classification of data and development of the training environment.

The E-learning environment is structured in courses. The portal trough the login, recognises each user, knows his level of learning and offers the correct learning material.

The aim of the e-learning is to transfer and disseminate the basic principles/applications of SMA technology to the stone sector. The training environment aims at stimulating SMEs in the development and validation of new SMA based concepts.

The e-learning is organised in main sections. Part of the material explains which is the overall architecture of the portal, what kind of tools can be found, and shows how to navigate. Other sections of e-learning are more specifically devoted to the world of SMAs. A collection of multimedia lectures, presentations, documents and papers can be retrieved, used online or downloaded by the users.

The content of the e-training section of the portal has been grown and changed up to the end of the project. The training environment, which has been designed by DAPP, has been continuously updated following the suggestions collected by SVIT during the training sessions. Inputs have been suggested also by the SMEs and IAGs involved in the project.

The courses developed are actually:

- Introduction to shape memory alloys
- Properties of the shape memory alloys
- SMA Applications
- The Design Support Tool tutorial
- The demonstrators

A substantial modification has been done also in the layout of the e-learning section with the interest to make it more similar to a training tool. An example of the previous layout versus the actual one has been highlighted in Figure 5.

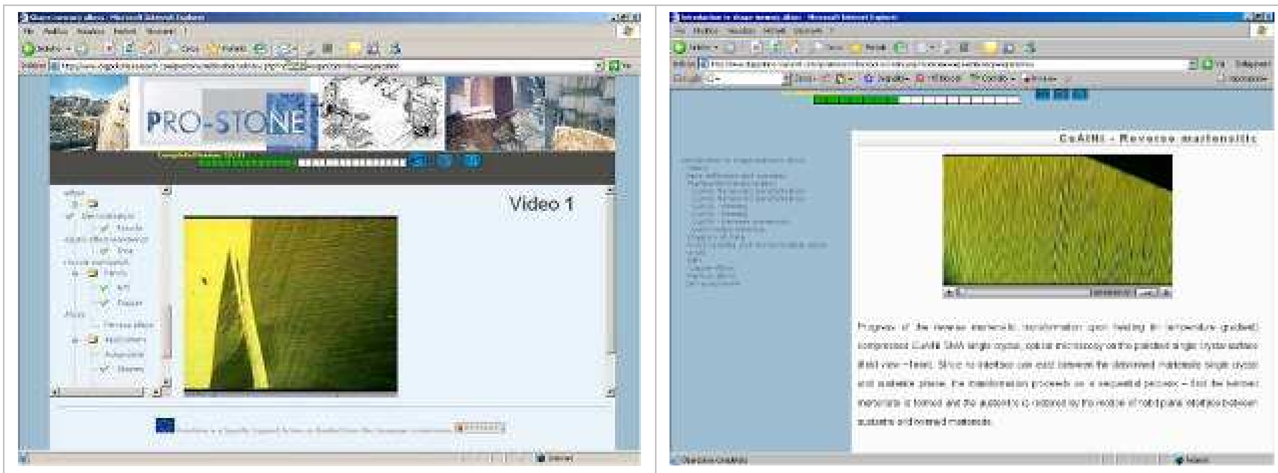


Figure 5 - Comparison between the old (left) and the new (right) e-learning layout

Thanks to this activity, the e-learning environment became friendlier and the effectiveness of the results has been improved.

3.4.3 Task 4.3 Development and optimisation of the Design Support System

Start Date: July 2006

Ending Date: June 2008

The Design Support System (DSS) was developed by DAPP, content and feedbacks were provided by the RTDs, the IAGs, the SMEPs, and the RTDs. It is formed by the following tools: SMA Technical Information, Stone repository, Machine repository, Application repository and Crack Propagation.

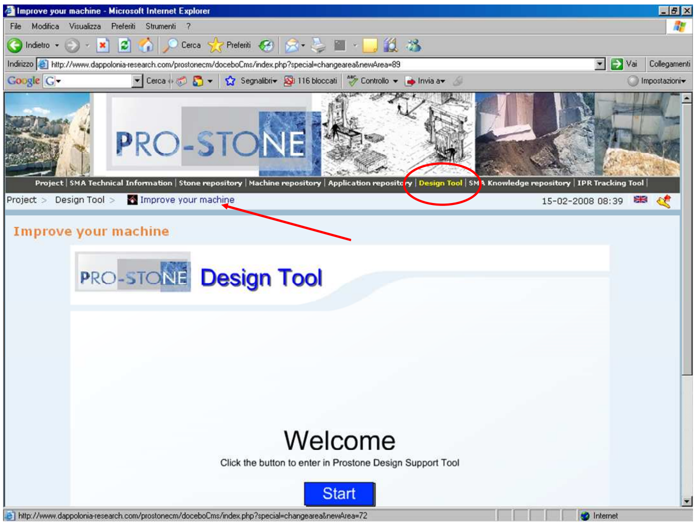


Figure 6 – Design Support System in the web platform

SMA Technical information allows retrieving physical, electromagnetic, mechanical, shape memory and economical information about a selected range of shape memory alloys (Ni-Ti, Ni-Ti-Cu, Cu-Zn-Al, Ni-Mn-Ga).

The databases of all the tools forming the Design Support System are constantly reviewed and updated thanks to the feedback and contribution of all partners. The overall architecture of the DSS has been designed, thus establishing links between the DSS and the databases previously mentioned.

The Design Support System integrates sample data and numerical models relative to basic SMA geometries.

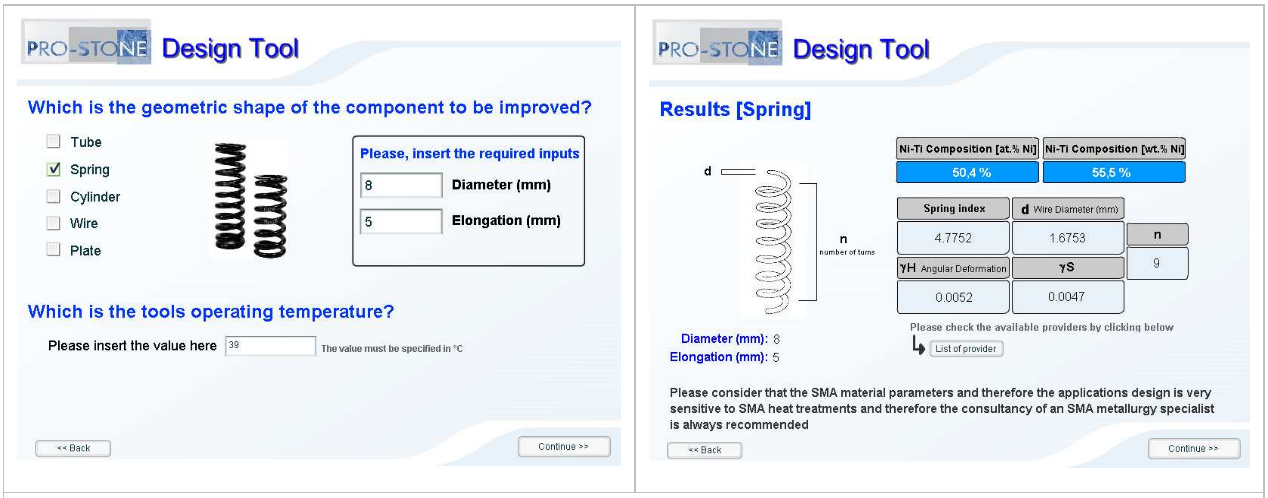


Figure 7 – Design Support Tool – Data entry and results

The user-friendly interface (see Figure 7) make also easier the interfacing of the repositories already presented in the website and make possible to the user retrieve the needed information in short time. All the fundamental geometric shapes have been modelled in order to cover the great majority of the applications of interest for quarrying and processing equipments.

The Design Support System has been developed taking into account the need to spread the SMA knowledge in an intuitive way, highlighting the several possibilities offered by these materials.

It is believed that this instrument is able to support the user of SMA in the inventive application process by means of specific examples and effective tutorials. The preliminary design phase could be there accomplished in a straightforward way.

3.5 WP 5: Validation of the Design Support System

Objectives: Prototyping of demonstrators according to the identified application opportunities, testing of the identified application opportunities and validation of the Design Support System.

3.5.1 Task 5.1 Prototyping of pilot demonstrators

Start Date: January 2007

Ending Date: December 2007

The prototyping phase began with the study of the requirement needed for the SMA inserts.

Many different alloys have been selected and investigated trough an exhaustive screening among the commercial available material. At the end of the project the NiTinol have been chosen as the most suitable for the three different applications thanks to its exceptional properties in terms of recoverable deformation in a wider temperature range and thermal even if such material is not so cheep like others.

In a second phase the most suitable forms with the detailed dimension for the demonstrators have been selected. IOP after supplementary testing sessions, needed to evaluate the answer of the sample to a high number of cycles under working condition, provided the SMA material in the ready-to-use form to the three industrial partners involved in the setting up of the prototype (Mincon, Tesimag and Ripamonti). Finally the technical requirements for the demonstrators have been duly defined thanks to several meetings on the field held among DAPP, IST, SVIT and the three industrial partners.

The main step followed from the Consortium was to develop the three different demonstrators (Figure 8)

Figure 8 – The demonstrators: (a) the blade holder; (b) the air splitting collar; (c) the cutting disc

1. SMA reinforced blade holder

The proposed solution is to utilize the above introduced functionalities of SMA - superelastic shock absorption and damping of vibrations with large strain amplitudes with shape recovering capability - to reduce the stress peaks and therefore to increase the lifetime of the blade while keeping the blade speed and/or vertical pressure on the blade constant or even higher.

The adopted solution has been to introduce the NiTi sheet elements into the holder in such a way that the tensile force from the pretensioning system is not directly transferred to the blade, e.g. on top of the blade as shown in Figure 9.

Figure 9 - Blade holder with SMAs inserts solution B

The system has been design and developed, being the SMEs partners heavily involved in the system requirements definition and with relevant inputs on the design of the system, on the testing methodology definition, and on the interpretation of the testing results. The prototyping phase and the following testing campaign have shown promising results well summarized in the deliverable D26.

2. SMA reinforced air splitting collar

This application concerns the use of an air gun barrel machine able of splitting rocks using pressurized air instead of explosive. The sealing effect is currently being achieved by inserting packs with sand powder between the gun barrel and the stone wall of the bore hole before injecting the pressurized air to the hole through the gun barrel. Although the equipment is functioning, it has limitations mainly related to the time-consuming and expensive task dealing with the sand preparation and insertion that needs to be repeated before every explosion.

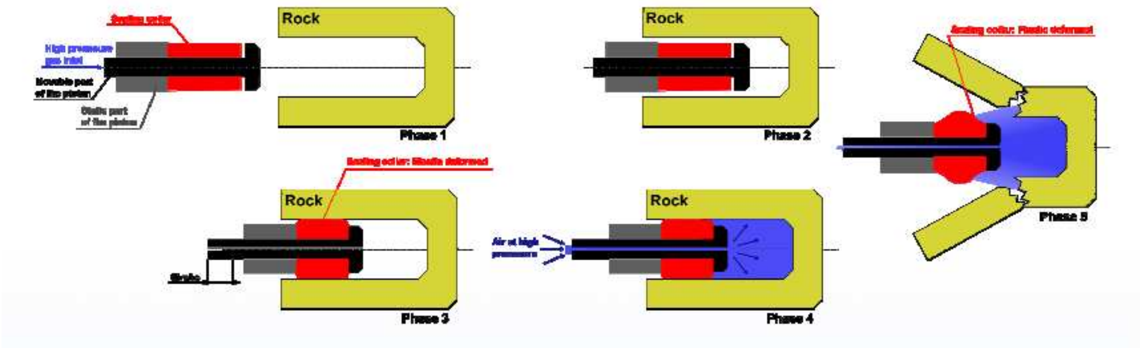


Figure 10 - SMA reinforced air splitting collar

The idea has been to integrate the superelastic NiTi wires into the collar with the aim of reinforcing it so that it can withstand the severe conditions occurring during the air pressure blast.

3. Giant cutting disc with smart SMA inserts

The proposed application aims at solving the problem related to high stress concentrations occurring during operation through insertion of active NiTi elements cut precisely from NiTi rolled sheet into the metallic rim of the blade or wherever else necessary. Such smart NiTi insert is expected to expand with increasing temperature counteract the undesired stress concentrations.

The main idea behind this application is to actively counteract the danger of the damage to cutting disc (intended for giant discs but tested on small discs) by modifying the stress concentrations through insertion of prestrained NiTi elements into holes cut in the cutting disc in places of maximum stress concentrations

Figure 11 - Design of the first mart cutting disc prototype

3.5.2 Task 5.2 Testing of pilot demonstrator and validation of the Design Support System

Start Date: April 2007

Ending Date: December 2007

The first months of this task have been used for the screening of the most suitable performances measurement system for each demonstrator. The aim was define the most suitable one in order to have a complete set of reliable parameters to evaluate the effectiveness of the SMA materials applications. Further activities are foreseen in the next 6 months finalised to the validation of the design support tool developed during the last year.

After many separate and collective technical meeting the performance measurement system have been selected:

- **Air splitting collar**: The system has to guarantee the sealing during the gun barrel “shot”. Taking into account the particular on/off nature of that kind of application the most efficient parameter is the failure average.
- **Blade holder**: The idea was to insert two load cells behind the block holder rail (the Audace machine cut two blocks at the same time) in order to measure the strength applied on the marble block from the blade when the blade hits the block. With the introduction of the SMA elements between the blade and the blade holder we expect that the peak of the strength is decreased but the useful work is increased.
- **Giant cutting disk**: For each option of inserts set-up, the strain distribution analysis has been carried out thanks to a non-contact laser extensometry. The best package (SMA material, rim thickness and insert positioning) has been selected and underwent to several tests (forces, energy, vibrations and analysis of diamond segment surfaces). We expected from these analyses the improvements from the speed and depth of cut to decrease cutting thickness and vibration.

The collaborative work (Tesimag-SVIT-IOP, Pondi-IST-IOP and Ripamonti-DAPP-IOP) was coordinated by DAPP taking advantage of the availability of the Design Support System. Finally, the design and validation testing of SMA elements for the selected demonstrators have been made.

Also a wide number of trials on the field have been necessaries in order to optimise the three prototypes as shown in the following Figure 12.



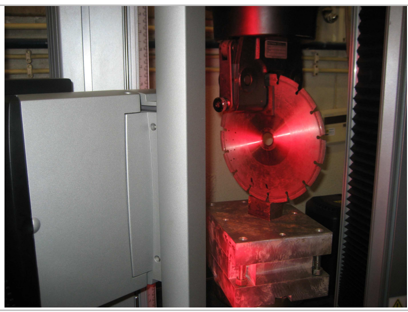


Figure 12 – The testing campaign: (a) the blade holder; (b) the air splitting collar; (c) the cutting disc

The results achieved show a good improvement of the tools' performance. The development of these prototypes demonstrates the applicability of the Shape Memory Alloys in the framework of the quarrying and processing equipment.

Testing campaign - The blade holder

The following graph (Figure 13) represents the comparison between the data acquisition of the three different setups (described below and identified with different line colours in the graph). On the Y axis is represented the force developed vertically on the stone during the hit between stone and blade and on the X axis is stated the progressive number of the sample acquired, thus it is an indication of the time passing. The blue line represents the behaviour of the blade holder without any insert. The violet line shows the behaviour of the machine with a steel insert in the blade holder. Finally the yellow line represents the behaviour of the machine with the insert of SMA.

The reduction of the force measured by the load cell is the proof of concept of the PRO-STONE idea. In fact the reduction of vertical force during the hit implies the rising of the horizontal force which is directly linked to the cut's effectiveness.

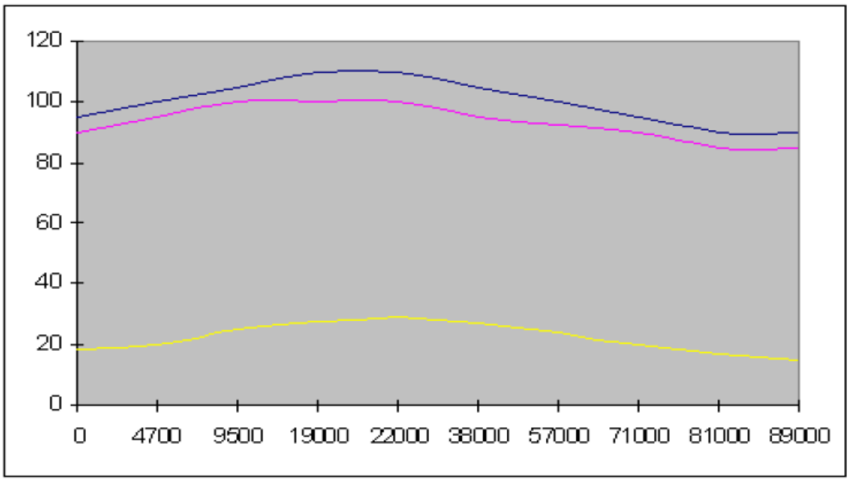


Figure 13 - Force behaviour during the stone-tool interaction

Testing campaign - The air splitting collar

Laboratory tests on NiTi reinforced collar

Various mechanical test were performed on the SMA reinforced air splitting collar to evaluate its mechanical properties and applicability for the required sealing functionality. It was found that the rubber collar can be loaded at very high strain rates and that even cyclic loading using large strain rates (10Hz) and large strain amplitudes for relatively large number of cycles (500) did not cause significant damage to the rubber material.

Next the NiTi reinforced collar was investigated in quasistatic compression tests.

Field tests

The trials performed represent a positive proof of concept showing the improved working performance of the SMA. During the preliminary tests by Ripamonti premises the reinforced collar has shown the needed sailing effect.

It was found that the NiTi spring indeed acts by large radial force on the collar which is assisted in its shape restoration by the SMA wire and comes back to the original position after that the blast take place. The NiTi wire reinforced collar suffers less damage during the blast and shows longer lifetime in service.

Finally the prototypes were subjected to field tests Figure 14 shows snapshots from the movie taken during the field testing campaign performed in the framework of the explosion work done for preparing the path of the TGV line near Frejus between Italy and France. The results achieved are in line with the laboratory test previously carried out and described above.

Figure 14 - Field Tests on NiTi reinforced collar on Ditta Ripamonti equipment in Frejus

Testing campaign - The cutting disc

IOP performed a series of neutron diffraction studies on steel coupons (cut from the cutting disc) with NiTi inserts as basic geometry. The aim was to obtain reasonable estimates for the static internal stress distribution around the embedded NiTi insert at room temperature and its evolution with

increasing temperature. These preliminary experiments were performed with the aim to obtain at least partial information on the stress gradients around the NiTi inserts.
Only preliminary but interesting results concerning the internal stress distribution around NiTi inserts in small steel sheet coupons and its temperature dependence have been made available.
IOP developed the SMA components according to the shape and dimension features generated by the Design Support System. In parallel, the simulation of the behaviour of the integrated system has been developed in order to have a theoretical confirmation of the expected results.

Laboratory and field tests have been performed taking advantage of the availability of the prototypes. Results of tests were beneficial for the set up of the SMA components for subsequent integration within the prototypes. The SMA based components integrated within the demonstrator were sensitized and the results, coming from these further investigations, were compared to the predicted data to validate the proper fulfilment of requirements and expectations of the Design Support System.

3.6 WP 6: Exploitation and Dissemination Activities

Objectives: Development of an effective securing of knowledge generated in the project, development of an effective dissemination and exploitation of the project results among and beyond the project partners.

3.6.1 Task 6.1 Protection of IPR

Start Date: July 2005

Ending Date: June 2008

The activities performed within such task have been mainly devoted to the development of the PRO-STONE Innovation Tracking System that enables to identify and track any innovative concept developed within the PRO-STONE activities, and to provide useful advices on the most effective way of protecting the intellectual properties identified.

Partners were proactively involved in the process of IPR protection since the very first step: the identification of the innovation.

Additionally, part of the activities performed in this Task has been devoted to the definition of an early IPR agreement. Such agreement has been shared and validated by all the partners of PRO-STONE as an extension of the Consortium Agreement signed at the beginning of activities..

During the development of the project, some discussions relative to intellectual property rights arose. PRO-STONE partners are started to be aware that SMA offer really interesting potentialities applied to the stone industry. During the project technical meetings several new ideas of potential applications were born. PRO-STONE partners expressed a great interest in the potential application of the Shape Memory Alloys to the stone industry. It has been recognised that the IPR starts to be even more important when new applications regarding SMA on already patented machines are studied.

On the basis of the results achieved with the three demonstrators during the last year of the project DAPP, IST and SVIT supported, from the IPR point of view, the IAG/SMEs involved. Concerning the latter the IAGs have initiated a plan together with the SME companies to detect other potential applications and, at the same time, manage the potentialities of the ideas developed in the framework of the project (demonstrators).

3.6.2 Task 6.2 Exploitation and Dissemination

Start Date: July 2005

Ending Date: June 2008

The project partners started the dissemination activities very soon: EUROROC launched these activities and the first dissemination event took place in Brussels on Tuesday, Sep. 27th, 2005 during the NEEIP meeting in which a wide representation of SMEs involved in the Stone industry from the EU-member states was present.

By Month 6 of the project, DAPP, with the support of EUROROC, prepared the Web site of the project http://www.dappolonia-research.com/pro-stone/home.php. In the web-site several public information concerning the project are reported. Furthermore, a private area has been created for the use of the project partners in order to exchange information and documents. By Month 12 a new release of the PRO-STONE website has been launched. Such new version is based on the inputs and feedback from the partners.

Furthermore the Project Presentation leaflet was ready by Month 6 of activities. The file has been distributed to the partners of the consortium to support them in their dissemination activities.

The SMEs associated to the IAGs had a fundamental role in the dissemination activities. The main instrument for direct dissemination has been the participation to workshops, public conferences with wide participation from European industry, research community, policy makers and media. Apart from these workshops, Euroroc used its Europe-wide industry network as a dissemination channel for project related information. ASSIMAGRA continued to disseminate the project results trough its weekly newsletter.

The work performed during the whole duration of the PRO-STONE Project, led to the definition of a proper plan for dissemination of the knowledge generated from the achievement of the Project activities, and to the definition of a suitable policy for its use and exploitation. All Partners of the Project participating to fairs, exposures and international events in Europe keep the results of the Project updated. It ensures correct information flow to the audience also outside the Consortium.

IAGs disseminated effectively the obtained results at regional, national and European level in close cooperation and agreement with the SMEs Core Group.

The final plan for the use and dissemination of knowledge was created in order to expose and outline the ensuring outgrowths of the whole project, their potential for exploitation process and to know how to operate this potential.

The main communications, relations and dissemination activities were:

- Production and distribution of project presentation materials such as brochures, newsletters and press release, media briefing.
- Development of the portal and Internet home page.
- Project presentations at scientific and professional conferences, workshops and exhibition.
- Publication of articles in scientific and professional journals.
- Dissemination flyers and direct e-mailing

Partner collaborated to produce publications (research papers, technical reports, articles and presentations) related to themes. It is great interest for the project to be able to have feedback form outside specialists in order to collect suggestions and to create debates.

As far as the exploitation is concerned the demonstrators that have been produced at the end of the project may also have interesting business potentials. The novel, high technology may be also appealing to "force" some PRO-STONE companies to transform the demonstrators in real industrial product. Another great possibility is the technology transfer of the SMA embedded into stone cutting machines into machines form other fields of industry.

The main dissemination events carried out during the project, are listed in the following table:

Event / Occasion	Date / Period schedule	Location	Present / by whom
Kick-off	July 2005	Massa (IT)	All
Technical meeting	6th July 2005	Lisbon (P)	All Portuguese partners
Technical visit	16th September 2005	MACEIRA premises	All Portuguese partners
3rd Month Meeting	21st September 2005	Genoa (IT)	RTDs, RIPAMONTI
Technical visit	23rd September 2005	MACEIRA premises	All Portuguese partners
Bilateral meeting	27th September 2005	Lisbon (P)	IST, MASERC and ASSIMAGRA
Technical meeting	September 2005	Athens (EL)	NTUA, MGA, MEGAMARM, LASKA
Technical visit	3rd October 2005	MACEIRA, quarries	IST, MACEIRA and ASSIMAGRA
Dissemination meeting	3-4 October 2005	Malmö (SW)	EUROROC
Seminar	7th October 2005	Massa (IT)	DAPP, SVIT, Stone SMEs ASSOINDUSTRIALI,

Dissemination meeting	14-16 October 2005	Alta (NO)	EUROROC
Publication	20-21 October 2005	Barcelona	IST
Technical meeting	27th October 2005	Massa (IT)	DAPP, Tesimag
Technical meeting	3rd November 2005	Lisbon (P)	IST, MASERC, MASEIRA, ASSIMAGRA, GALRAO
Dissemination meeting	4-5 November 2005	Mainz (D)	EUROROC
Bilateral meeting	9th November 2005	MASERC premises	IST, MASERC, ASSIMAGRA
Dissemination meeting	15-16 November 2005	Mainz (D)	EUROROC
Dissemination meeting	21st December 2005	Paris (F)	EUROROC
Technical meeting	24th November 2005	MACEIRA premises (P)	All Portuguese partners
Bilateral meeting	25th November 2005	MASERC premises (P)	IST, MASERC and ASSIMAGRA
Dissemination meeting	25th November 2005	Massa, Nicolai Diamond, Benetti	DAPP, SVIT
Technical meeting	27th December 2005	Lisbon (P)	IST, MACEIRA, MASERC, GALRAO, ASSIMAGRA
Bilateral meeting	11th January 2006	GALRÃO premises	IST, GALRÃO and ASSIMAGRA
Dissemination	11th January 2006	Paris (F)	EUROROC
Dissemination (workshop)	12th January 2006	Huizingen (B)	EUROROC
Seminar	17th January 2006	ASSIMAGRA premises	All Portuguese partners + invited participants
6th Month Meeting	January 2006	Brussels (BE)	All
Dissemination meeting	20-21 January 2006	Mainz (D)	EUROROC
Technical meeting	March 2006	Lisbon (P)	IST, MACERC, MASEIRA, ASSIMAGRA, GALRAO, DAPP
Technical Meeting	March 2006	Wiesbaden (D)	EUROROC, Schwieren, Z&W, ZDN
Dissemination (workshop)	24-25 March 2006	Vienna (A)	EUROROC
Dissemination	31 March/1 April 2006	Technipierre (Belgium)	EUROROC
Dissemination (workshop)	10-13 May 2006	Piedra (Spain)	EUROROC
Dissemination activities	31 May/3 June 2006	IMM Carrara (Italy)	SVIT, ASSOIND., TESIMAG

(workshop, fair)			
12th Month Meeting	July 2006	Lisbon (P)	All
Publication	September 2006	Swiat-kamienia (Poland)	ABRA
Training Session	29th September 2006	Athens (Greece)	DAPP, SVIT, Core Group SMEs
Public. ROQ MAQUINA	5th October 2006	Verona (IT)	SVIT
Dissemination (workshop)	5-8 October 2006	Verona (IT)	EUROROC, SVIT, DAPP, TESIMAG
Dissemination	26-27 October 2006	Brussels (Belgium)	EUROROC
Dissemination	1-3 November 2006	Juuka (Finland)	EUROROC
Training session	29th November 2006	Athens (G)	NTUA, SVIT, DAPP
Technical meeting	18th January 2007	Verbagna (Italy)	DAPP, Assoindustriali, Ripamonti, Tesimag, SVIT, IST, IOP
Dissemination	19-20 January 2007	Mainz, National Stone Centre (Germania)	Euroroc
Dissemination	22-23 January 2007	Brussels (Belgium)	Euroroc + invited participants
Dissemination (Stone Conference)	25-27 January 2007	Hallein (Austria)	Euroroc
Dissemination	6-7 February 2007	NEEIP meeting (Belgium)	Euroroc + invited participants
Dissemination (conference)	21-22 February 2007	Warsaw (Poland)	Euroroc + invited participants
Dissemination (conference)	22-24 February 2007	Ulm, National Stone Conference (Germany)	Euroroc + invited participants
Technical meeting	5th March 2007	Galarao quarries (Portugal)	IST, Galrao and Assimagra
Technical meeting	15th March 2007	Carrara (Italy)	SVIT, TESIMAG
Dissemination meeting	19th March 2007	Carrara (Italy)	DAPP, Italian SMEs from the stone sector
Dissemination	30-31 March 2007	Mainz, National Stone Centre (Germania)	Euroroc
Technical meeting	8th May 2007	Naples (Italy)	Technical meeting with

			expert in SMA
Dissemination	11-13 May 2007	Mainz, National Stone Centre (Germania)	Euroroc
Technical meeting IST,	20th May 2007	Maceira (Portugal)	Maceira, Galrao and Maserc
Technical meeting	1st June 2007	Assimagra (Portugal)	All portuguese partners
Dissemination (conference)	04-09 June 2007	Stone+Tech International, Nuremberg	Euroroc + invited participants
24th months project meeting	07-08 June 2007	Fair, Nuremberg	All
Training session	6-9 June 2007	Nuremberg (D)	DAPP, SVIT, Core Group SMEs
Technical meeting	14th June 2007	Lisbon (Portugal)	ALL PORTUGUESE PARTNERS
Dissemination	18th June 2007	Massa Carrara (Italy)	ASSINDUSTRIA SME members
Technical meeting	25-29 June 2007	Lund (Sweden)	IOP
Technical meeting	27-29 June 2007	Brno (Czech Republic)	IOP
Dissemination	29th June 2007	Lisbon (Portugal)	ALL PORTUGUESE PARTNERS
Technical meeting	16-17 July 2007	Carrara (Italy)	SVIT + TESIMAG
Dissemination	21st July 2007	TESIMAG premises – Carrara (Italy)	DAPP + invited participants
Dissemination	6th August 2007	Nicolai Diamond premises – Carrara (Italy)	SVIT + invited participants
Technical meeting	27th August2007	Carrara (Italy)	SVIT-TESIMAG
Dissemination	28-30 August 2007	Scan. Group - Malmö (Sweden)	EUROROC + SCAN. GROUP
Dissemination	11th September 2007	ASSIMAGRA premises - Porto Mos (Portugal)	All Portuguese partners + invited participants
Technical meeting	15th September 2007	Ornavasso (Italy)	DAPP – RIPAMONTI
Technical meeting	17-19 September 2007	Carrara (Italy)	SVIT-TESIMAG
Dissemination	25th September 2007	ASSIMAGRA premises - Porto	All Portuguese partners + invited participants

		(Portugal)	
Technical meeting/training session	6th October 2007	Verona (Italy)	EUROROC Members – SVIT
Dissemination (fair)	5-10 October 2007	Marmomacc International Fair -Verona (Italy)	EUROROC, SVIT, DAPP, TESIMAG + invited participants
Dissemination	12th October 2007	ASSIMAGRA premises - Borba (Portugal)	All Portuguese partners + invited participants + members of IAPMEI
Technical meeting	15th October 2007	Carrara (Italy)	SVIT-TESIMAG
Dissemination / seminar	10-16 October 2007	Munchen (Germany)	DAPP + invited participants
Dissemination	18-22 October 2007	Verona – Stone (Italy)	MASERC
Dissemination / seminar	19th October 2007	Regional Chamber of Commerce premises - Ancona (Italy)	DAPP + Regional Chambers of Commerce and representatives of regional SMEs
Dissemination	22th October 2007	Signa (Italy)	DAPP + SMEs active in the Tuscany Region
Dissemination (fair)	25-28 October 2007	Innovation Fairs - Florence (Italy)	DAPP + participants
Technical meeting	7th November 2007	Lisbon (Portugal)	All Portuguese partners
Dissemination (fair)	7-9 November 2007	SINOTEC International Fair – Lisbon	All Portuguese partners + institutional organisations + invited participants
Technical meeting	8-9th November 2007	Bergamo (Italy)	SVIT – DAPP – NTUA – RIPAMONTI
Dissemination / workshop	14-15 November 2007	F.D.P. Centro Techn. – Cáceres (Spain)	EUROROC + invited participants
Dissemination	19-20 November 2007	Amsterdam (Nederlands)	DAPP + invited participants
Technical meeting	22-23-28 November 2007	Carrara (Italy)	SVIT-TESIMAG
Technical meeting	30th November 2007	Galrao premises (Portugqal)	All Portuguese partners
Technical meeting	3 December 2007	Milano (Italy)	DAPP-RIPAMONTI
Technical meeting	4th December	Athens	NTUA – GMA – Laska

	2007	(Greece)	
Technical meeting	5th December 2007	Maceira premises (Portugal)	All Portuguese partners + tool manufacturer
Technical meeting	3-4-7-18-19 December 2007	Carrara (Italy)	SVIT-TESIMAG
Dissemination / workshop	12th December 2007	Regional Chamber of Commerce premises – Ancona (Italy)	DAPP + Regional Chambers of Commerce and representatives of regional SMEs
Technical meeting	11 January 2008	MACEIRA	All Portuguese partners
30 Month meeting	18th January 2008	Prague (Czech Republic)	All
Technical meeting	3 of February, 2008	MACEIRA	All Portuguese partners + machine builder
Dissemination and training	8-9, 15-16 February 2008	Hauzenberg, Granite Center, Bavaria, Germany	Euroroc -information and training for three countries Austria, Germany and Switzerland
Dissemination - fair	19- 22 February, 2008	KIEV – Build – (Ukrain)	GALRÃO
Dissemination (stone conference)	20th March 2008	Murcia, Centro Technologico, Cehegín, Spain	Euroroc + invited participants
Technical meeting 8	28 March, 2008	IST	All Portuguese partners
Technical meeting	3 April 2008	IST	All Portuguese partners + invited participants
Dissemination	7-9th April 2008	Paris, UNICEM, Rue Alfred Roll Centre, maîtres des pierres, France	Euroroc
Networking/ seminar	5-7 May 2008	Prague (Czech Republic)	IOP, 40 participants 35 from Europe, 5 from US and Asia
Dissemination (preparation to fair)	9 May 2008	Marmomacc, Verona (Italia)	Euroroc
Dissemination meeting (seminar)	19 May 2008	ASSIMAGRA – Porto Mós (Portugal)	All Portuguese partners + institutional organisations + invited participants
Dissemination (conference)	20 May 2008	National Stone Conference, - Bern, Switzerland	Euroroc + invited participants
Dissemination	20-24 May 2008	TEKTÓNICA,	GALRÃO

		Lisbon fair	
Final meeting / press release	27-28 May 2008	Carrara (Italia)	All
Training session	13 June 2008	SVIT premises Massa (Italia)	SVIT + Italian SME active in stone sectors
Training session	28 June 2008	Lisbon (Portugal)	All Portuguese partners + invited SME from Portugal and Spain
Dissemination	29-30 May 2008	Brussels, Raw Materials Supply Group, Belgium	Euroroc
Dissemination/ Workshop	1 July 2008	SVIT premises Massa (Italia)	SVIT + Representatives from Indonesian Republic Government

Table 4 - Dissemination and training activities

3.7 WP 7: Training Activities

Objectives: Development of appropriate and effective courseware, training material and training methodology to ensure an effective transfer of knowledge to SMEs belonging to the stone sector.

3.7.1 Task 7.1 Training

Start Date: September 2005 (planned Start Date: March 2006)
Ending Date: June 2008

As stated in the technical annex, Training Activities have been subdivided into two distinct phases: the first phase covered part of first-step Training activities, where development of appropriate courseware, covering basic principles and properties on Shape Memory Alloys, as well as an appropriate training methodology has started to be subsequently applied for the e-training of Shape Memory Alloys, their properties and their potential to be applied in the stone sector. In order to guarantee the transfer of know how to SMEs as a broader aim of the project, feedbacks over the developed courseware and methodologies were needed to maximize the effectiveness of the training. The approach followed has been to 'locally-customised' training activities organised in concomitance with the local dissemination workshops, the Stone SMEs have been reached in a more focussed and interactive way, allowing for a mutually benefiting two-way knowledge flow between industrial participants, acquiring conception and technical know-how and researcher-trainers obtaining feedback on industry requirements and experience.

Training materials about SMA have been collected from RTD performers and public available literature and web sites. These materials have been organized on the base of content, target audience, possible training usage.

To summarize the main achievement of the activities are reported below:

- collection of feedbacks about a preliminary tutorial aimed to inform SMEs about SMAs. collected feedback will be used to understand and evince further information needs;
- setup of the global training activities strategy. Key points of training activities have been identified and will undergo a detailed analysis;

- identification of a set of tools for e-learning activities, performed interactively with WP4 as the platform itself belongs to WP4 but the choice is strongly influenced by the training methodology.

The training courses have been carried out in two different ways, courses for demonstration in companies and closed group seminars and the other ones, prepared online as e-learning courses deployed through the e-learning platform.

Training sessions have been performed. The availability of a native language version of the presentations and courses facilitates the compression of lecture, and so as all the presentations, whenever possible, were made in local languages or in English.

The participants of the training sessions were divided in two main groups:

- Enterprise's decision makers (CEOs, Owners)
- Technical decision makers (Designers, Consultants)

Whenever possible, answers, in particular those regarding detail level, were valued accordingly to attendees role inside SME.

The customer satisfaction feedback form was submitted to 57 attendees being a member of SME core groups, from which 51 have been completed.

About 50% of trainees’ population belongs to machine manufacturing both for processing and post-processing or to designer/consultants, 43% belong to processing chain (processing and post-processing) and quarry, 7% to associations.

While the training session, technical meetings and seminars have been organised, the companies have been asked to appoint personnel directly involved in the decision making process, because this type of personnel influenced directly the development process of companies and is essential in a successfully technology transfer process.

The content quality feedbacks were very satisfactory. The attendees have been satisfied with the contents, agreeing with the courses material selection. The feedback forms have brought also suggestions for improvement highlighting the need of a wider availability of technical material. Finally a proper training path for each kind of participants has been setup.

Only 30% of feedback forms reported knowledge on Shape Memory Alloys before attending the training session. The result was not surprising, because 50% of the trainees were involved in economic management of the company, so excluding the answers coming from personnel with administrative roles, 60% of technical staff already knew SMAs at different levels.

The training activities could be subdivided in three different groups:

- Contents
- Interactive training
- On Line/Offline Training

Training material have been collected, prepared and reviewed since the very beginning of the project.

The courses have been developed accordingly to the following structure:

- Introduction to Shape Memory Alloys
- The properties of shape memory alloys
- SMA Applications
- SMA Design tool
- PROSTONE prototypes

The online version of the course takes advantages also from the use of multimedia, material like animations and interactive examples.

Access in the on-line training website has been monitored in order to understand the use of the platform by the Core Group members and by SMEs granted of access right.

The preliminary analyses of logs showed that PROSTONE website is used by a high number of visitors.

The statistics related to the number of contacts reflect mostly the geographic distribution of Project consortium.

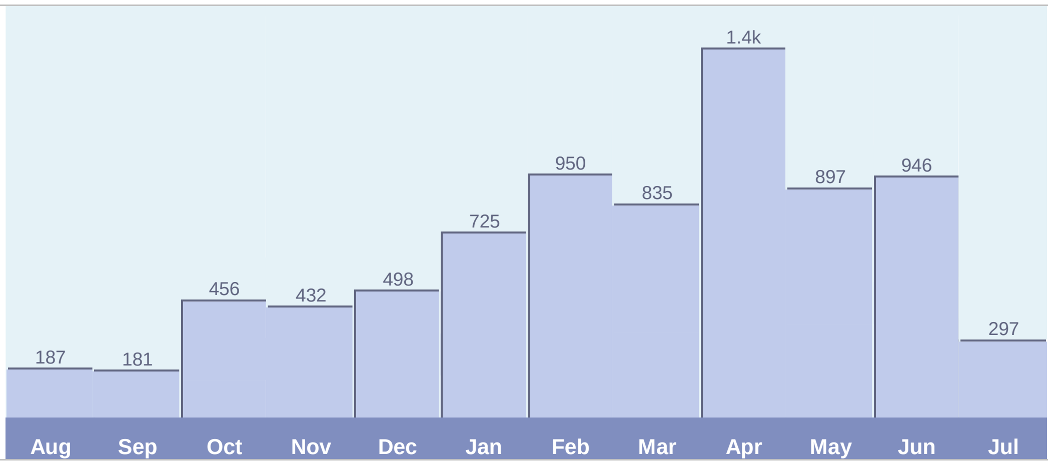


Figure 15 - Last year statistics (unique sessions)

As continuous vocational training is crucial for managers, technicians and engineers, PRO-STONE partners are promoting the mobility of industry staff to attend dedicated innovation and technology sessions, for small trainees groups, at research centres or universities and will prepare content for user-friendly on-line tutorials for maximum flexibility for life-long learning concepts ranging from on-the-job learning, to evening schemes to high-intensity crash courses. A series of training activities has been performed, the most relevant are summarised below:

29/09/2006	Athens (Greece)	DAPP, SVIT, Core Group SMEs
6-9/06/2007	Nuremberg (D)	DAPP, SVIT, Core Group SMEs
13/06/2008	SVIT Premises (MASSA)	SVIT + Italian SME active in stone sectors
28/06/2008	Lisbon (Portugal)	All Portuguese partners + invited SME from Portugal and Spain

The objective of this workpackage is to provide an efficient Project Management from the technical point of view, to ensure the quality of all RTD and Innovation Related Activities, as well as from the consortium point of view, to ensure punctual delivery of reports and deliveries, budget and financial control and on-time communication between the project Consortium and the European Commission.

3.8 List of deliverables and Milestones

All the scheduled deliverables have been prepared and annexed to this 12th Month Progress report. The list of the deliverables is reported in the following table (Table **5**). The list of the Milestones is provided in Table **6**. With respect to the future deliverables no time schedule deviation is expected. Similarly, no deviation is expected in the achievement of future Milestones.

Table 5: Deliverables List

Del. no.	Deliverable name	Workpackage no.	Date due	Actual/Forecast delivery date	Estimated indicative person-months	Used indicative person-months	Lead contractor
D1*	Early IPR Agreement	6	M3	M3	0,5	0,5	DAPP
D2*	Innovation tracking system	6	M6	M6	1,5	1,5	DAPP
D3*	First version of the PRO-STONE Homepage	6	M6	M6	2,25	2,25	EURO
D4*	PRO-STONE Dissemination Plan	6	M6	M6	2	2	EURO
D5*	Project presentation	6	M6	M6	2	2	EURO
D6*	Progress report at month 6	8	M6	M6	1	1	DAPP
D7*	Technical SMA information system	3	M10	M10	14,5	14,5	DAPP
D8*	Testing equipment	3	M10	M10	17	17	NTUA
D9*	Progress Report at month 12	8	M12	M12	1,5	1,5	DAPP
D10 *	Design and setup of Knowledge Web Portal architecture	4	M12	M12	23	23	DAPP
D11 *	Characterisation of stones mechanical properties	2	M14	M14	15,5	15,5	SVIT
D12 *	Models for quasi-static propagation of cracks and fractures in stone blocks	2	M14	M14	13,5	13,5	DAPP

Table 5: Deliverables List
(Continuation)

Del. no.	Deliverable name	Workpackage no.	Date due	Actual/Forecast delivery date	Estimated indicative person-months	Used indicative person-months	Lead contractor
D13 *	Critical review of machinery and equipment and identification of representative geometries	1	M18	M18	34	34	DAPP
D14 *	Identification of Potential Application Opportunities	1	M18	M18	30	30	IOP
D15 *	Preliminary version of Plan for Use and Dissemination of Knowledge	6	M18	M18	3	3	DAPP
D16 *	Mid-Term Assessment Report at month 18	8	M18	M18	2	2	DAPP
D17 *	Development of an e-training section for demonstration and training	4	M18	M18	23	23	DAPP
D18 *	First version of Training Plan	7	M21	M21	20	20	SVIT
D19 *	Evaluation of stone-tool interaction under dynamic processing conditions	2	M22	M22	14,5	14,5	IST
D20 *	Characterisation of SMA joints	3	M24	M24	14,5	14,5	NTUA
D21 *	Characterisation of forces and displacement from SMA actuators	3	M24	M24	10	10	IOP
D22 *	Characterisation of actuation strategies	3	M24	M24	13,5	13,5	DAPP
D23 *	Characterisation and modelling of fatigue behaviour of superelastic SMA components	3	M24	M24	9	9	NTUA
D24 *	Progress Report at Month 24	8	M24	M24	1	1	DAPP

Table 5: Deliverables List
(Continuation)

Del. no.	Deliverable name	Workpackage no.	Date due	Actual/Forecast delivery date	Estimated indicative person-months	Used indicative person-months	Lead contractor
D25 *	Development of the Design Support System through the integration of models	4	M30	M30	11	11	DAPP
D26 *	Prototyping of pilot demonstrators and validation testing	5	M30	M30	59,5	59,5	IOP
D27 *	Progress Report at month 30	8	M30	M30	1,5	1,5	DAPP
D28 *	Knowledge Web Portal: common services and application maintenance	4	M36	M36	10,5	10,5	DAPP
D29 *	Final version of Plan for Use and Dissemination of Knowledge	6	M36	M36	2,25	2,25	DAPP
D30 *	PRO-STONE Dissemination Report	6	M36	M36	2	2	EURO
D31 *	Training Reports based on feedbacks of the SME Core Group members	7	M36	M36	34,5	34,5	SVIT
D32 *	Final Report at month 36	8	M36	M36	1,8	1,8	DAPP

***) Delivered on schedule**

Table 6: Milestones List

Milestone no.	Milestone name	Workpackage no.	Date due	Actual/Forecast delivery date	Lead contractor
1*	M1 - Preliminary identification of Potential Application Opportunities	1	Month 6	Month 6	DAPP
2*	M2 - First release of the Knowledge Web Portal	4	Month 12	Month 12	DAPP
3*	M3 - Ornamental stones characterisation and study of stone-tool interaction and cracks propagation	2	Month 14	Month 14	IST

Table 6: Milestones List
(Continuation)

Milestone no.	Milestone name	Workpackage no.	Date due	Actual/Forecast delivery date	Lead contractor
4*	M4 - Mid-Term Assessment Meeting	8	Month 18	Month 18	DAPP
5*	M5 - Characterisation of SMA elements with respect to fatigue behaviour, generated forces and displacements and analysis of applicable joining methods and actuation strategies	3	Month 24	Month 24	IOP
6*	M6 - Design Support System	4	Month 30	Month 30	DAPP
7*	M7 - Successful industrial validation and Plan for Use and Dissemination of Knowledge	6	Month 36	Month 36	EUROROC
8*	M8 - Final Assessment Meeting	8	Month 36	Month 36	DAPP

***) Achieved on schedule**

4 Consortium Management

Consortium management falls under the activities described within WP 8 (Consortium Management). During the project D'Appolonia, as coordinator, has been fully involved in the project management and coordination of the consortium. The collaboration in the consortium has been always characterised by a high level of commitment from the team leaders and the participating organisations. In order to coordinate and produce all the described activities a wide number of meetings have been organized across Europe. The commitment and interest has grown up continuously during the project from the first steps of idea generation to the final validation of the developed prototypes. In the framework of this three year project many communication between partners have been necessary to discuss strategies, problems and solution for research, dissemination, training and exploitation activities. It has been a focus also the continuous collection of feedback from all the partners about the content and usability of the tutorials (web portal, e-learning tool, design tools, dissemination material, IPR strategy, etc.) developed in the framework of the PRO-STONE project.

Several bilateral meetings between the Core Group of SMEs, the IAGs and the RTD performers have been held to guarantee the maximum efficiency of the work done. Moreover, RTD performers (plus EUROROC) organised in-house meetings at the premises of almost all the Core Group of SMEs and IAGs for assessing the achieved results and then the plan for use and dissemination of knowledge.

Every three months, the Technical Management Committee assessed the status of activities. Approximately 57 technical meeting have been performed in order to solve the developments problems arisen during the whole project but increased in the setting up of demonstrators phase.

Furthermore, RTD performer (plus EUROROC) organised in-house meetings at the premises of almost all the Core Group of SMEs and IAGs for assessing the specific knowledge requirements and details.

Obviously the ideas and material collected have been circulated among the partner and have been argument of many conference calls in order to harmonise each contribution with the requirement of project plan.

During the second year of the project also a withdrawal of two project partners (Mincon LTD and Megamarm LTD) and the following introduction in the consortium of the new partners Pomdi Herramientas de Diamante and G. Chrissafakis S. have been managed following the procedure established by the European Commission as widely described in the Final Management Report

No further problems have been incurred from the starting up to last month of the project. No delays on the time-schedule activities have been suffered.

The main Project Meeting has been successfully held at the partners premises (IAGs and RTD partners) all over the Europe. The Overview of the work and technical discussion have been performed. Below a table summarising the project management meetings held during the last year of the project (Table 7).

Table 7 - Project Management meetings

Meeting	Date	Place	Present
Kick-off	July 2005	Massa (IT)	All
Technical meeting	November 2005	Lisbon (P)	IST, MASERC, MASEIRA, ASSIMAGRA, GALRAO
3rd Month Meeting	September 2005	Genoa (IT)	RTDs, RIPAMONTI
Technical meeting	September 2005	Athens (EL)	NTUA, MGA, MEGAMARM, LASKA
Technical meeting	October 2005	Massa (IT)	ASSINDUSTRIA, TESIMAG, ECSEL, SVIT, BIK, SODEX
Technical meeting	December 2005	Lisbon (P)	IST, MACEIRA, MASERC, GALRAO, ASSIMAGRA
6th Month Meeting	January 2006	Brussels (BE)	All
Technical meeting	March 2006	Lisbon (P)	IST, MACERC, MASEIRA, ASSIMAGRA, GALRAO, DAPP
Technical Meeting	March 2006	Wiesbaden (D)	EUROROC, Schwieren, Z&W, ZDN
12th Month Meeting	July 2006	Lisbon (P)	All
12 month update meeting	July 20, 2006	IOP ASCR, Prague	Heller, Novak, Sittner, Landa
Management meeting	Aug. 27-28, 2006	Shannon, Ireland	Mincon, DAPP
Technical meeting	Aug. 30, 2006	Verbania, Italy	Ripamonti, DAPP
Technical meeting	Sept. 2, 2006	RIPAMONTI premises (Italy)	RIPAMONTI, DAPP
Technical meeting	Sept. 5, 2006	ASSIMAGRA premises (Portugal)	All Portuguese partners
Technical visit	Sept. 16, 2006	GALRÃO premises (Portugal)	All Portuguese partners
Technical meeting	Sept. 20, 2006	Capua, Italy	DAPP and external expert on smart materials
Technical meeting	Sept. 22, 2006	Genoa, Italy	Sittner
Technical visit	Sept. 23, 2006	MASERC premises (Portugal)	All Portuguese partners
Technical visit	Sept. 28, 2006	Rome, Italy	DAPP and external expert on smart materials
Technical visit	Sept. 30, 2006	Carrara, Italy	DAPP, SVIT and Tesimag
Technical meeting	Oct. 3, 2006	Rome, Italy	DAPP and external expert on smart materials
SMA wire exp. meeting	Oct. 5, 2006	IOP ASCR, Prague	Sittner, Pilch, Novak, Landa, Heller, Crhan, Zidek, Sedlak, Molnar, Kopecek, Simek, Gartnerova
Technical meeting	Nov. 10, 2006	Signa, Italy	DAPP, SVIT, ASSINDUSTRIA, TESIMAG, ECSEL
Actuator exp. meeting	Nov. 16, 2006	IOP ASCR, Prague	Sittner, Pilch, Landa, Heller
Technical meeting	Nov. 22, 2006	MACEIRA premises (Portugal)	All Portuguese partners

18th month project meeting	Nov. 30, 2006	NTUA premises, Athens, Greece	DAPP, EUROROC, ZDN, ASSINDUSTRIA, GMA, Ripamonti, MINCON, Tesimag, TECHMI, Maserc, SCHWIEREN, Laskaridis, SVIT, IST, IOP and NTUA
Seminar	Dec. 11, 2006	ASSIMAGRA premises (Portugal)	All Portuguese partners + invited participants
Technical meeting	Dec. 13, 2007	RIPAMONTI premises (Italy)	Ripamonti and DAPP
Application meting	Dec. 21, 2006	IOP ASCR, Prague	Sittner, Pilch, Landa, Heller, Crhan, Zidek, Sedlak, Molnar
Technical meeting	Dec. 18, 2006	Rome	DAPP internal iechnical meeting
Technical meeting	Jan. 9, 2007	Galrao premises (Portugal)	All portuguese partners
Technical meeting	Jan. 9, 2007	Assimagra premises (Portugal)	All portuguese partners
Management meeting	Jan. 18, 2007	Ornavasso (Italy)	DAPP, RIPAMONTI
Technical meeting	Jan. 29, 2007	Maceira premises (Portugal)	All portuguese partners
Technical meeting	Jan. 31, 2007	Maserc premises (Portugal)	All portuguese partners
Management meeting	Feb. 12, 2007	Florence (Italy)	SVIT, DAPP
Technical meeting	Feb. 14, 2007	Carrara (Italy)	SVIT, TESIMAG
Technical meeting	Feb. 19, 2007	Rome (Italy)	DAPP Internal technical meeting
Technical meeting	Mar. 05, 2007	Galarao quarries (Portugal)	IST, Galrao and Assimagra
Technical meeting	Mar. 15, 2007	Carrara (Italy)	SVIT, TESIMAG
Technical meeting	Mar. 21, 2007	Rome (Italy)	DAPP internal technical meeting
Dissemination meeting	Mar. 19, 2007	Carrara (Italy)	DAPP, Italian SMEs from the stone sectro
Technical meeting	Apr. 3-4, 2007	Rome (Italy)	DAPP internal technical meeting
Technical meeting	Apr. 12, 2007	Carrara (Italy)	SVIT, TESIMAG
Technical meeting	Apr. 12, 2007	Maserc (Portugal)	Maceira, Galrao and Maserc
Technical meeting	May 8, 2007	Naples (Italy)	Technical meeting with expert in SMA
Technical meeting	May 15, 2007	Carrara (Italy)	SVIT, TESIMAG
Technical meeting	May 20, 2007	Maceira (Portugal)	IST, Maceira, Galrao and Maserc
Technical meeting	Jun. 1, 2007	Assimagra (Portugal)	All portuguese partners
24th months project meeting	Jun. 07-08, 2007	Stone+Tech Internationa Fair, Nuremberg	All partners
Technical meeting	Jun. 13, 2007	Carrara (Italy)	SVIT, TESIMAG
Management meeting	Jun. 25, 2007	Carrara (Italy)	DAPP, TESIMAG
Technical meeting	Jun. 26, 2007	Galrao (Portugal)	All portuguese partners
Technical meeting	16-17/07/2007	Carrara (Italy)	SVIT-TESIMAG
Technical meeting	27/08/2007	Carrara (Italy)	SVIT-TESIMAG
Project Meeting	September 2007	Brussels (B)	DAPP
Technical meeting	15/09/2007	Ornavasso (Italy)	DAPP – RIPAMONTI
Technical meeting	17-19/09/2007	Carrara (Italy)	SVIT-TESIMAG
Technical meeting	6/10/2007	Verona (Italy)	EUROROC Members – SVIT
Technical meeting	15/10/2007	Carrara (Italy)	SVIT-TESIMAG
Technical meeting	7/11/2007	Lisbon (Portugal)	All Portuguese partners
Technical meeting	8-9/11/2007	Bergamo (Italy)	SVIT – DAPP – NTUA – RIPAMONTI

Technical meeting	22-23-28/11/2007	Carrara (Italy)	SVIT-TESIMAG
Technical meeting	30/11/2007	Galrao premises (Portugqal)	All Portuguese partners
Technical meeting	4/12/2007	Athens (Greece)	NTUA – GMA – Laska
Technical meeting	5/12/2007	Maceira premises (Portugal)	All Portuguese partners + tool manufacturer
Technical meeting	3/12/2007	Milano (Italy)	DAPP-RIPAMONTI
Project Meeting	10-11 December 2007	Brussels (B)	DAPP
Technical meeting	3-4-7-18-19/12/2007	Carrara (Italy)	SVIT-TESIMAG
Technical meeting	11 January 2008	MACEIRA	All Portuguese partners
30 Month progress meeting	18^{th} January 2008	Prague (Czech Republic)	All
Technical meeting	3 February 2008	MACEIRA	All Portuguese partners + machine builder
Technical meeting	28 March 2008	IST	All Portuguese partners
Technical meeting	3 April 2008	IST	All Portuguese partners + invited participants
Networking/ seminar	5-7 May 2008	Prague (Czech Republic)	IOP, 40 participants 35 from Europe, 5 from US and Asia
Seminar	19 May 2008	ASSIMAGRA – Porto Mós (Portugal)	All Portuguese partners + institutional organisations + invited participants
Final meeting / press release	27-28 May 2008	Carrara (Italia)	All
Project Meeting	4-5 June 2008	Brussels (B)	DAPP

No major changes or modifications to the project work plan have been performed from the scheduled work-programme. The activities are completed as scheduled; the following picture shows the Gantt Chart (Figure 16).

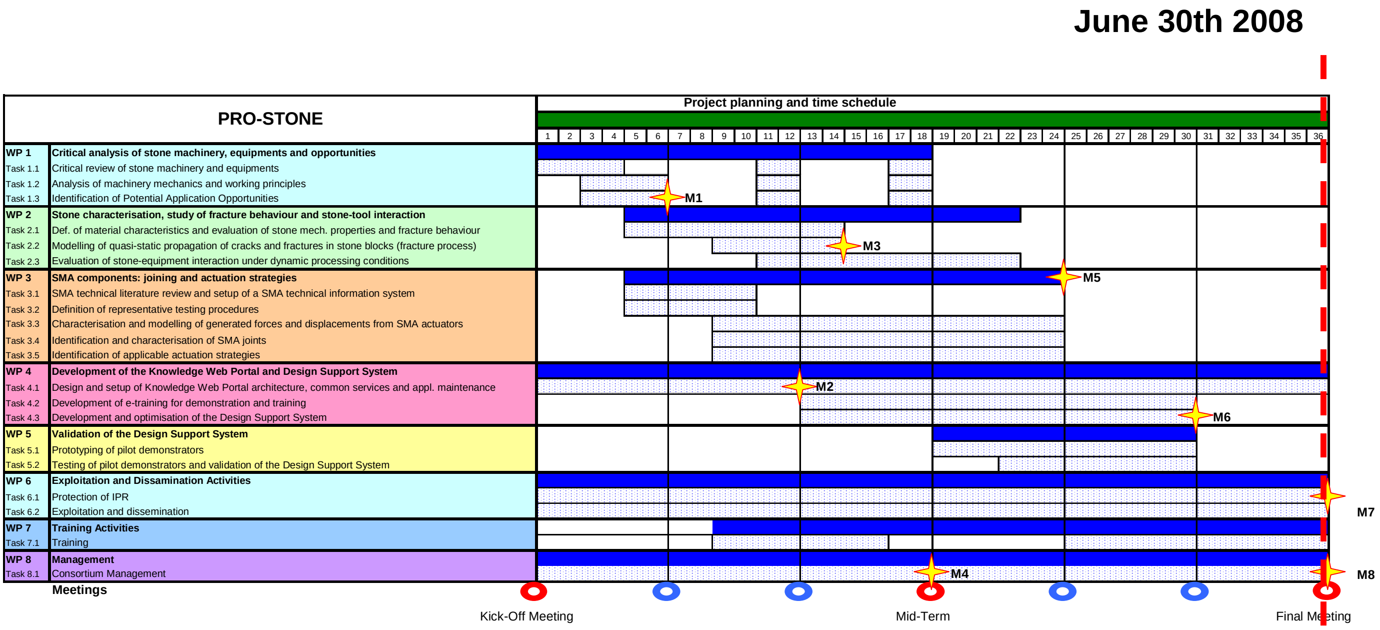


Figure 16 – Gantt chart