Project no. NMP2-CT-2006-026789

POLYTECT

Polyfunctional Technical Textiles against Natural Hazards

Co-operative Research Project

Month 37 – Month 48
Final Activity Report

Period covered: 1st September 2009 / 31st August 2010

Date of preparation: 05th November 2010

Start date of project: 01/09/2006

Duration: 48 Months

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Project coordinator organisation name: D'Appolonia S.p.A.

Revision 0

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1 Publishable executive summary

Textile materials are extensively used in construction. In geotechnical applications, these materials provide reinforcement for slopes, retaining structures, roadways, embankments, as well as various drainage structures. In masonry applications, textiles are growing in importance as they provide a non-intrusive technique to provide reinforcing strength to a structure (damaged or undamaged). Common applications include localized crack repair, the reinforcement of critical walls, or the wrapping of existing columns. Across geotechnical and masonry applications, textile materials improve structural performance under service conditions and provide protection in the event of earthquake, landslide, accident, or other unforeseen loading condition.

Several views of damage caused by natural hazards

Embedding sensors of different types into textile materials enables several important advantages. Structural health monitoring (SHM) can be conducted during construction, under in-service conditions, and post tragedy (i.e. after an earthquake). Such measurements can be used before or after an event to take preventive measures (before) or to assess the state of the structure (after). Measurements over time can be used to track changes in structural performance allowing for maintenance and repair actions when appropriate. In the case of chemical sensing, sensor embedded textiles can be used to detect environmental contamination.

The Polytect Project:

POLYTECT
Integrated Project for SMEs

www.polytect.net

Polyfunctional Technical Textiles against Natural Hazards (POLYTECT) is an Integrated Project for small to medium enterprises (SMEs) under the 7th Framework Program. The project involves 27 partners from 12 countries and is coordinated by D'Appolonia S.p.A., Italy. The project duration is 4 years which began in August, 2006 and will finish in August, 2010. A listing of all project partners is provided at the end of this summary.

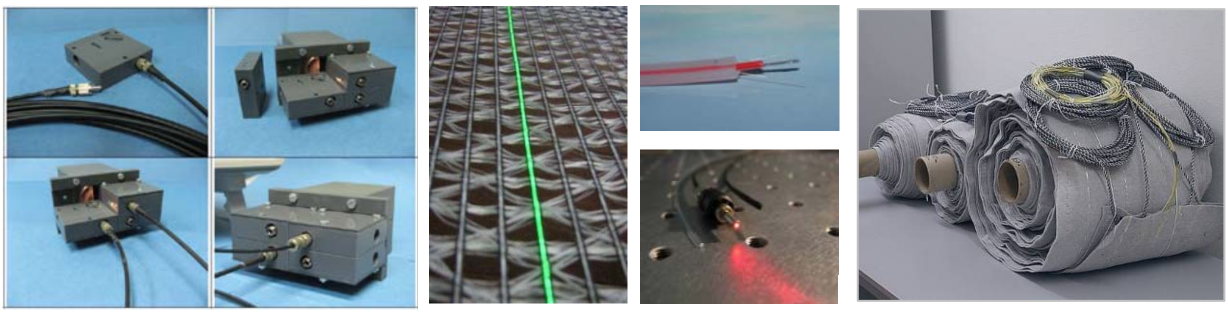
The aim of Polytect is to provide reinforcing strength and monitoring capability for geotechnical and masonry applications through the industrial production of multifunctional technical textiles. Polytect spans and includes the following activities:

- The development of new and novel sensors. These sensors include fiber optic sensors, piezoelectric sensors, chemical sensors, and sensitive textile fibers (coatings)
- The development of new and novel sensor interrogation systems and data processing techniques
- The development of nanoparticle-based mortars and adhesives

- The integration of sensors into warp-knitted textiles for geotechnical and masonry applications (two dimensional and rope like structures)
- The evaluation of these products in a laboratory environment
- The development of numerical models for the employment of these materials
- The field testing of project products in real world, tough, and rugged environments

The client for this work are all parties responsible for the design and safe performance of roads, retaining walls, embankments, railways, landfills, drainage structures, dykes, masonry structures (buildings and bridges), as well as historical monuments (cultural preservation). The different functions the textile structures are captured in the *project objectives* which are:

- to increase ductility and structural strength;
- to monitor stresses, deformations, acceleration, water level variation and pore pressure;
- to detect presence of fluids and chemicals;
- to measure structural health.



Several Polytect Products: A multi-channel stackable interrogation system (Interlab), a sensor embedded textile pattern (STFI), novel fiber optic sensors (Smartec), and a sensor-embedded filter mat (Selcom)

Highlighted Project Progress: Polytect is organized into three general phases. They are *Phase I*: Product Development, *Phase II* Product Laboratory Testing and the Development of Supporting Numerical Models, and *Phase III*, Product Validation in Field Conditions. All the phases have been successfully completed: During the 4th year of the project, Phase III was conducted including a series of field tests both for reinforcing masonry structures as well as for geotechnical applications, the two main project areas. Polytect provided, at its end, the capability to obtain information across a variety of geotechnical and masonry applications. Even if the project is currently closed, Polytect partners supported by D'Appolonia have planned or are going to plan how to enter the market of civil engineering with the products developed within Polytect.

Textiles: Over 21 multifunctional, sensor-embedded textile patterns have been designed, manufactured by industrial partners, and tested. This has involved the adaptation of industrial warp-knitting machines and the produced materials meet the same durability standards as their non sensor-embedded counterparts. This work has been primarily conducted by the research and testing facility STFI with machine adaptation expertise from the company Karl Mayer and then the industrial production capability of the companies Selcom, Alpe Adria Textile, and Extreme Materials.

Sensitive Fibers: Piezoelectric powders that can be dispersed in polymer solutions have been developed for the investigation of coating applications. Separately, fiber optic chemical sensors have been developed for temperature and moisture measurements. The chemical sensors have been investigated for the use in landfills that operate as bioreactors (meaning the control of temperature and humidity results in a more efficient landfill). This work has been primarily conducted by the research leaders UCM (Spain), CSGI (Italy) and Centexbel (Belgium) with the industrial production capability of Interlab (Spain) for acquisition units and BG Polymers (Israel) for polymer production. Company Iridex (Romania) provided supporting actions for the field test activities at the selected landfill in Romania.

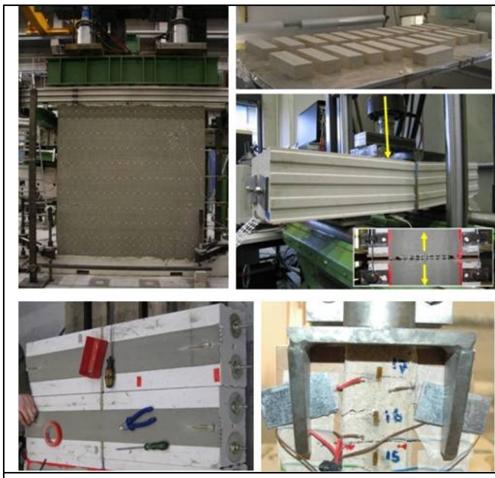
Sensors: Different applications require different types of measurements. For example, the monitoring of a dyke may require distributed sensing over many kilometres and periodic measurements. In contrast, the monitoring of a masonry structure may require point or distributed sensing with measurements that can be taken at high frequency. Polytect has developed a range of sensors and sensing acquisition systems that include the materials Glass Optical Fibers (GOF), Plastic Optical Fibers (POF), and sensitive textile fibers and which employ the sensing techniques of Fiber Bragg Gratings (FBG), Optical Time Domain Reflectometry (OTDR), distributed Brillouin sensing, piezoelectric sensing, conductive polymer coatings. This work has been primarily conducted by the sensor development partners Smartec (Switzerland), Safibra (Czech Rep.), Light Structures (Norway), and Interlab (Spain) supported by the federal research center BAM (Germany) and the Universidad Complutense de Madrid (Spain).

Acquisition System, Data Processing Techniques, and Supporting Software: Each sensor requires different interrogation techniques (optical or electrical). One challenge in the use of fiber optic sensors is the cost of the acquisition system. In Polytect, several partners have constructed low cost acquisition units. Two are currently available. The goal here was to get these units in the thousands of euros instead of tens of thousands of euros. Concurrently, each system requires a data processing technique and supporting software that translate the received light signals into physical measurements of interest. This work occurred at Interlab (Spain), Smartec (Switzerland), Safibra (Czech Rep.), Light Structures (Norway) and the federal research center BAM (Germany).

Laboratory testing at STFI (Chemnitz, Germany), the University of Kassel (Germany), the University of Karlsruhe (Germany), and at CETMA (Brindisi, Italy)

Laboratory Testing: Hundreds of tests have been carried out partner laboratories to study the performance of different textile material configurations, the effects of different mortars, the effects of different textile coatings, and the behaviour and performance of the sensors embedded in the textiles.

The result is a deep understanding of these wide area reinforcing textiles, knowledge on how to test and evaluate them, expertise in how to apply them, and mostly importantly the optimisation of fibre types, fibre orientations, the embedded sensors, coatings, and mortars. In combination with field test activities, the result is two products ready for commercial sale. For masonry applications, *SELCOM* is producing the **SENTEX 8300** (sensorized reinforcing textile SENTEX8300) that can be outfitted with polymer optical fibres for distributing sensing and with glass optical fibres for dynamic measurements. *D'Appolonia* is offering consulting expertise for the application and use of the SENTEX8300. For geotechnical applications, *GLÖTZL* is offering the product **GEDISE** (Geotechnical Distributed Sensing) that provides distributed measurements for up to 500 meters in while simultaneously providing soil reinforcement.

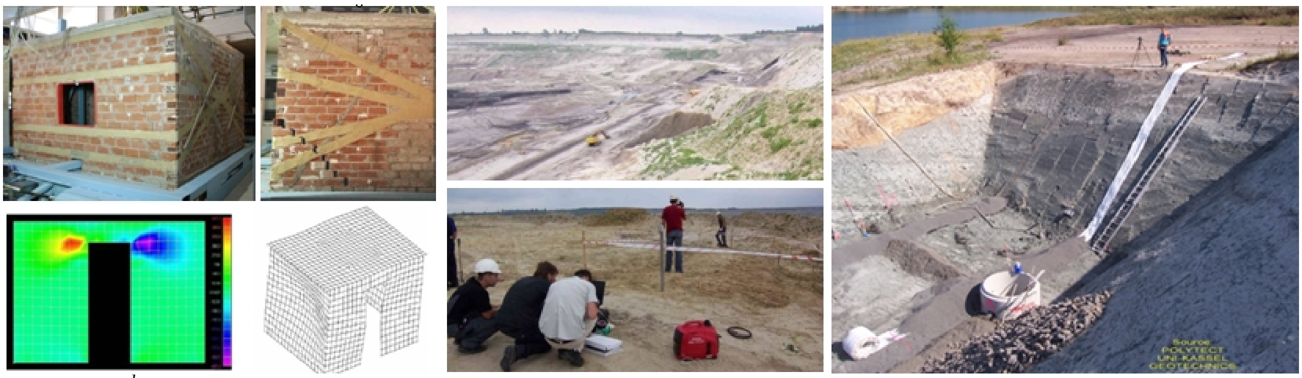


Polytect Laboratory Testing

For Buildings: SENTEX8300

For Soil: GEDISE

Field Testing: The 3rd year brought a host of field testing opportunities across the project. They began with the testing campaign of a single story masonry structure at IMMG (Greece) on a shaking table. Representative of many structures in Greece and throughout the Mediterranean, these tests enabled a better understanding of such structures when subjected to earthquake, the development of assessment methods to determine if a structure is damaged or not, and how to best reinforce the structure with reinforcing textiles. Next, two separate field tests in Poland were conducted to assess road embankments at a brown coal mine. Led by partners Gloetzl and BAM, these tests helped the mine owner take repair actions before a slope of concern worsened risking the safety of personnel, equipment, and production. Lastly, in Germany, sensor embedded textiles were utilized to monitor the repair of a persistent slope failure that was encroaching on nearby homes.



Polytect 3rd Year Field Tests: Earthquake testing at IMMG (Greece), monitoring road embankments in Poland by partners Glötzl (Germany) and BAM (Germany), and the monitoring of a slope failure in Germany by the University of Kassel (Germany).

In the 4th, Polytect continued to build upon all aspects of project success. In focus are targeted education and training venues, product specification sheets, application guidelines, outreach to engineering professionals, and three special field tests events. The first of these field tests involved the monitoring of landfills with chemically sensitive rope like sensors. The test location was the

Albota Landfill in Romania which has been offered by the company Iridex (Romania). The test was coordinated by Universidad Complutense de Madrid. The second was the testing of a 2 storey stone structure reinforced with SENTEX8300 and subject to earthquake forces in collaboration with the European Centre for Training and Research in Earthquake Engineering (EUCENTRE) in Pavia, Italy. The test was coordinated by D'Appolonia. The third test was again the shaking table test of a two storey brick (instead of stone) masonry building, coordinated by IIT Madras with the support of KIT and carried out in May-August 2010 in India. In this case, three buildings have been tested: one un-reinforced, as reference, and two reinforced with textile strips and full coverage multiaxial textiles, both produced and made available by SELCOM.

Polytect 4th Year Field Tests: Shaking table test of stone masonry building (Italy), of brick masonry building (India) and test of rope like structures with chemical sensors in a landfill (Romania)

Polytect awarded at JEC 2010

The POLYTECT Seismic Wallpaper won the JEC Innovation Award in section Building and Construction. The award was accepted by a representative of the partners at JEC in Paris on April 13th. The Intelligent composite "Seismic Wallpaper" is used for the reinforcement, strengthening, monitoring and management of civil infrastructure (masonry buildings) vulnerable to earthquakes.

When applied as a full-coverage solution and tested in large-scale laboratories (that conduct national standardisation testing for Germany), this solution provided over 200% increases in structural strength (max. load) and over 200% increases in structural ductility (max. displacement after the material yielding). These composite features embedded sensors so that measurements can be taken before, during, and after seismic events. These measurements can be static or dynamic. Engineers utilize such data to control new construction, to assess and quantify the benefit of retrofit actions, and to help manage the structure over time.

POLYTECT Partner Representatives accepting the JEC Award 2010 for the best innovation in the Building & Construction sectors for the Polytect "Intelligent Seismic Wallpaper" concept

Table of Polytect Partners

Participant Role*	Participant No.	Participant name	Participant short name	Country	Date enter project**	Date exit project**
CO	1	D'Appolonia	DAPP	I	1	48
CR	2	STFI	STFI	D	1	48
CR	3	APC Composites	APC	SW	1	48
CR	4	Karl Mayer MALIMO Textilmaschinenfabrik GmbH	MAYER	D	1	48
CR	5	SELCOM srl	SELCOM	I	1	48
CR	6	Karlsruhe Institute of Technology	KIT	D	1	48
CR	7	Light Structures	LS	NO	1	48
CR	8	Kassel Univ. Institute of Geotechnics	UNI-KASSEL	D	1	48
CR	9	IMMG	IMMG	EL	1	48
CR	10	CETMA	CETMA	I	1	48
CR	11	Iridex	IRIDEX	RO	1	48
CR	12	Centexbel	CENTEXBEL	B	1	48
CR	13	Centre for Colloidal and Surface Research (CSGI)	CSGI	I	1	48
CR	14	SLSpezial-Nähmaschinenbau Limbach GmbH & Co	SLS	D	1	48
CR	15	Alpe Adria Textile	AAT	I	1	48
CR	16	Extreme Materials S.r.l.	EXTREME	I	1	48
CR	17	BG Polymers	BGP	IS	1	36
CR	18	Safibra	SAFIBRA	CZ	1	48
CR	19	IKH	IKH	EL	1	48
CR	20	SMARTEC	SMARTEC	CH	1	48
CR	21	Grupo Interlab	INTERLAB	E	1	48
CR	22	Polystal	POLYSTAL	D	1	48
CR	23	TexClubTec	TEXCLUBTEC	I	1	48
CR	24	Universidad Complutense de	UCM	E	1	48

		Madrid				
CR	25	Federal Institute for Materials Research and Testing	BAM	D	1	48
CR	26	Gloetzl	GLOETZL	D	1	48
CR	27	Indian Institute of Technology Madras (India)	ITI MADRAS	IN	1	48
CR	28	BG Technologies	BGT	IS	37	48

2 Section 1 – Project objectives and major achievements during the reporting period

Overview of General Project Objectives and Relation to the State of the Art

Textile materials are used in construction in both ground and building structures. The retrofitting of existing masonry walls and soil structures is particularly important for earthquake protection of historic buildings and protection of earthworks against landslides. Unreinforced masonry structures are highly vulnerable because being originally designed mainly for gravity loads they often cannot withstand the dynamic horizontal loads in case of strong earthquakes. Soil structures, such as embankments, are subjected to landslides after heavy rainfalls or during earthquakes.

Hence the necessity to develop efficient methods for the retrofitting of existing masonry buildings and earthworks and of related monitoring systems to possibly prevent the structural damage.

The broader aim of POLYTECT is the development of new sensor-embedded, multifunctional textile structures for application in construction for the retrofitting of masonry structures and earthworks. The different functions the textile structures are captured in the *project objectives* which are:

- to increase ductility and structural strength;
- to monitor strains, deformations, and acceleration;
- to detect presence of fluids and chemicals;
- to measure structural health.

Enabling technologies include the combination of warp-knitted grid-like reinforcing basic structure and rope-like reinforcement, the incorporation of optical fibres into textiles as well as the incorporation of sensing fibres e.g. by coating fibres with nanocrystalline piezoceramic materials or conductive polymers\alloys.

The proposed breakthroughs include the: use of textile material as load-bearing part of the building; use of multifunctional textiles for stabilisation and monitoring; use of nanostructured materials to tailor the interface properties; incorporation of sensors based on nanocrystalline piezoceramics and optical fibres, development of an impedance-based health monitoring technique.

Summary of Recommendations at the Previous Reporting Period and Actions Taken

At the three year meeting held in Venice at the end of September 2008 the remarks from the project officer and project technical reviewer were very positive. Overall it was observed that the quality of the consortium, the management of project activities, and the results of the project are very good.

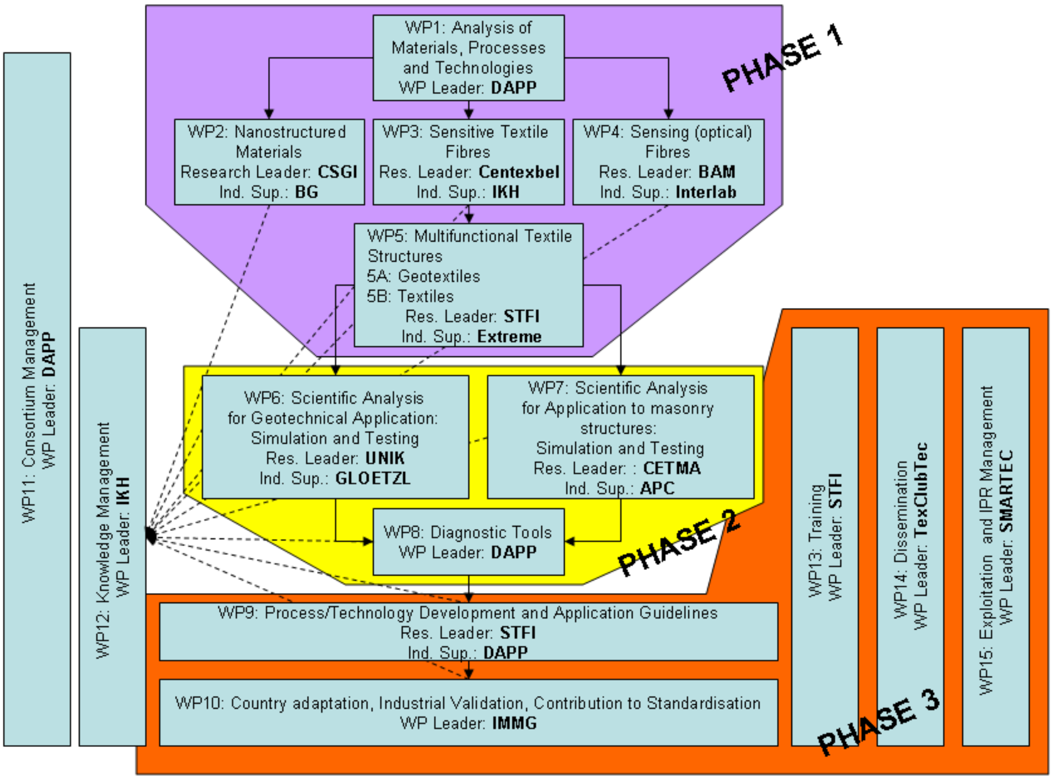
The comments on the specific WP are summarised hereafter:

1) **WP2 and WP3**: the recommendation of extension of duration given at previous review resulted in the achievement of good results. The Commission is encouraging to go forward with the development in these WPs and in particular the patents, transfer of knowledge, and exploitation of knowledge for the results obtained.
2) **WP4 and WP5**: these WPs have been completed with excellent results which will be consolidated in the other WPs

3) **WP6 and WP7**: many activities have been carried out for the testing and characterization of materials. During the first part of their development more emphasis was given to the monitoring and sensing aspects rather than the reinforcing, since the reinforcement of earth structures and masonry structures with textiles was already proven and therefore did not require further research. However during the laboratory and field tests, also the reinforcing capabilities were demonstrated.
4) **WP8**: needs to focus on a specific diagnostic approach.
5) **WP10**: demonstration activities are well developed. A good planning is recommended in order to be able to effectively validate the work and proof the developed technologies.
6) **WP11**: the project management is very good.
7) **WP12**: is getting better. Although initially very broad in its scope of activities, they are beginning to focus. The recommendation is to develop only things which are useful and needed by the partners. An additional useful function of the KMT is the incorporation of the Exxploitation Result table, which could be effectively linked to the product data sheets which are starting to be formulated.
8) **WP13**: the recommendation is to focus on the audience to be targeted in order to be really efficient
9) **WP14**: dissemination activities are excellent and the expectations are now very high so the recommendation is to be sure to deliver the claimed results, in order to avoid a boomerang effect.
10) **WP15**: The updated version of the Exploitable Results is excellent and it will become the basis of the PUDK (Plan for Using and Dissemination of the Knowledge). The state of the art should also be referenced and the costs for each of the products and services should also be quantified.

Summary of the objectives of the Reporting Period, Work Performed, Contractors Involved, Challenges Faced and Actions Taken to address these Challenges

The project flow diagram is shown below. During year four, phase II and phase III of the project were active. To review, **Phase 2** consists of the activities carried on in WP6, WP7 and WP8. The role of WP6 and WP7 is to test in a laboratory environment (Uni-Kassel, KIT, and CETMA) the integrated sensor embedded textiles and sensor systems produced in phase 1 for geotechnical applications (WP6) and for masonry applications (WP7). WP8 is on the contrary the highlights of WP6 and WP7 techniques towards the development and the adoption of a diagnostic tool for processing the different types of sensors data. Finally, **Phase 3** consists of WP9, WP10, WP13, WP14, and WP15 which are field testing, country adaptation, training, dissemination, and exploitation.



Year 4 saw the **fulfilment of Phase II and Phase III activities**.

With respect to Phase II, WP6, WP7 and WP8 activities were completed. In WP6 partner DAPP and Uni-Kassel completed the experimental tests and the numerical simulations of the geotechnical sensor-embedded textiles and developed a real-world field test that addressed an existing problem and forced large scale production of the textile materials. In WP7, CETMA and KIT completed the masonry experimental tests campaign, while DAPP took care of the numerical simulations of the uni-axial and the full-cover reinforcing solutions to validate results and to develop tools that assist the planning for the use of Polytect materials. In parallel with WP6 and WP7, WP8 activities were completed. DAPP, with contributions of IMMG, developed diagnostic tools and methods for the assessment of structural integrity: in particular the definition of a methodology for damage detection using distributed textile sensors was achieved.

With respect to Phase III, WP9, WP10, WP13, WP14 and WP15 activities were completed. In WP9 the manufacturing process description and the application guidelines for textile materials were completed. WP10 saw the completion of demonstration and validation activities with reference to earthworks and masonry applications. Training activities were conducted within WP13, including the realization of webinars by DAPP, STFI and CETMA for the dissemination of the Polytect knowledge, together with Polytect WP14. Within WP15, some of the most powerful results of Polytect have been exploited by means of data sheets and brochures, in particular, for masonry applications, the two reinforcing solutions developed by Polytect were decided to strategically being fully disseminated with the realization of two ad-hoc brochures to give visibility to the full-scale experimental tests, their results and their interpretation in comparison with numerical simulations.

Selected 4 Year Project Level Highlights

Primary meetings during the year:

42 Month Meeting	(Praha: 24-26 March 2010)
48 Month (Final Meeting)	(Genova: 28-29 July 2010)

The attainment of two milestones: M8 (Closure of experimental campaigns), M9 (Knowledge management platform) and M10 (Demonstration activities complete) have been achieved.

The completion of the deliverables: All the deliverables have been completed. Most of them referred to WP6, WP7, WP8, WP9, WP10, WP13, WP14 and WP15. In addition two reports referring to two cases study for masonry applications have been deployed. The Plan for Disseminating and Using the Knowledge has been finalized.

Revision of the ER Tables: As previously noted under *recommendations and actions taken*, the ER tables were completed in a document that captures nearly all project activities and the related exploitation partners.

From product development to product commercialisation: During the Final Meeting, the industrial results achieved by each SME partner were presented. Many of these products have been or are going to become a commercial product. The following can be highlighted:

AAT: The Kemafil® production process (new production machine) is on the market.
Extreme: Machinery adaptations and sensitive 3D ropes incorporating SMARTEC sensors. 4.5 km of the material was produced and used in a project in the USA in collaboration with SMARTEC. One of the challenges identified was prairie dogs that unexpectedly and habitually ate the rope with the sensor fibre.
SMARTEC: Several sensors (SMARTape, SMARTprofile, and SmartTube), the service SHM Live, SMARTGeoTex ROPE, and SMARTGeoTexFABRIC) are all commercially available. Several have already made it into the Rocktest product catalogue and initial sales have occurred (SMARTprofile and SMARTGeoTex ROPE). SMARTEC will continue to work with POLYTECT partners to offer these products as a service.
BGP/BGT: BGP-POLYTECT 5 is now available as a commercial product with technical data sheet. This product is an adhesive specifically designed for fastening multifunctional textiles to unreinforced masonry structures. The product has already been on display at several exhibitions attended by BGP/BGT.

The expansion of Polytect into an international collaborative initiative: Inspired from Polytect, D'Appolonia now leads an international collaborative platform entitled **Industrial Smart Material Applications (ISMA)**: *Manufacture, build, monitor, assess, predict, and manage* as part of the IMS program. This initiative has approximately 35 members worldwide and includes leading industries, universities, and research centres in the area of smart materials. The platform had its kickoff meeting 11 September, 2009 at the 7th International Workshop on Structural Health Monitoring held at Stanford University, Stanford, CA, USA.

New Commercial Alliances: In tandem with exploitable results, several partners have formed commercial alliances growing from Polytect activities. Examples include the pairing of DAPP and Smartec in an initiative called SHMLive by which DAPP provides engineering consulting for SHM and Smartec provides instrumentation and support, the pairing of Gloetzl and Alpe Adria Textile to manufacture and sell the product GEDISE, and the pairing of Smartec and Extreme Materials to produce long geotextiles for distributed sensing.

Bulleted Highlights:

- 03 August 2009-22 March 2010: Geotechnical sensors field tests at the old open mining area of Zimmersrode, Kassel, Germany

- 14-15 January 2010: Shaking table tests of a strips reinforced masonry building at IMMG, Athens
- 24-26 March 2010: Polytect M42 Meeting, Praha
- 13-15 April 2010: JEC Awards ceremony, Paris
- 28 April - 01 May 2010: Chemical sensors tests at Uni-Kassel
- 02-07 June 2010: Chemical Sensors Landfill tests at Albota, Romania
- 16-17 June 2010: Shaking table tests of a reinforced full-scale full-cover masonry building at Eucentre, Pavia, Italy
- June 28-July 2, 2010: Fifth European Workshop on Structural Health Monitoring, Sorrento, Italy
- 28-29 July 2010: Polytect M48 (Final) Meeting, Genova
- September 2010: DORNBIRN 49th Man-Made Fibers Congress
- April-September 2010: Shaking table tests of a full-scale strips and full-cover reinforced masonry building at Indian Institute of Technology, Madras, India

Workpackages Highlights

WP6: Laboratory as well as field tests for geotechnical applications were conducted and completed during the 4th year of the project. Numerical models were developed in parallel. All the 7 tasks and were completed and the deliverables provided. D6.7 in particular summarized all the activities conducted within WP6.

WP7: Final laboratory and field tests for masonry applications were conducted and completed during the 4th year of the project. Numerical models were developed in parallel. Transfer of knowledge from WP7 to WP8 (Diagnostic tool) and WP10 (Country adaptation) was implemented.

WP8: was completed by the end of the project. With the contribution of partner IMMG, DAPP developed a series of diagnostic tools and the adoption of different methodologies for damage detection of masonry structures. Significant contribution to the interpretation of sensors data for dynamic measurements were achieved, and a series of models investigating how to employ Polytect sensor embedded textiles and which type of information could made available to engineers were developed.

WP9: WP9 activities started in the reporting period (M37) and concluded at M48. Process/Technology development and applications guidelines were developed with the aims of defining manufacturing/process adaptation and a suitable quality assessment procedure for the production of the multifunctional textiles.

WP10: Based on the knowledge transferred from experimental tests and numerical simulations carried on WP6, WP7 and WP8, a relevant number of field validation tests (Chemitz, Belchatow, Zimmernode, Albota, IMMG, Pavia, ITT Madras) were completed and/or conducted during the reporting period. In particular field shaking table tests in Pavia were the results of a successful proposal, submitted by DAPP, in the SERIES program (EU FP7) to conduct testing with Polytect materials at one of the SERIES program facilities, the EUCENTRE (Pavia).

WP12: Partner IKH made available a final version of the knowledge management tool (KMT) and the sensor measurement management system (SMMS). In particular, the KMT will remain available after project completion.

WP13: Training activities were completed during the last year of the project. Partner STFI structured a series of training modules (both content and format) completed by the partners, in addition to lectures in forms of webinars, referring to different Polytect topics (technical textiles for reinforcement, sensors, SHM, etc..), which were made available for educational purposes.

WP14: Dissemination activities were conducted and increased during the last year of the project as a contribution to the progress of the State-of-th-Art in the research areas of POLYTECT and to open the way to the market applications. Conferences, invited lectures, exhibition were part of the dissemination strategy. Among the others, Polytect partners presented their contribution on European and International technical textiles and composite conferences, on Structural Health Monitoring, Geotechnical and Smart Materials conferences, on sensors and sensing systems conferences.

WP15: SMARTEC and DAPP spent a significant effort to set the basis for an efficient exploitation of the Polytect results, products and activities, in particular into the market of civil infrastructures.

3 Section 2 – Workpackage progress during the reporting period

3.1 General

The Work Packages active in the 4th year of the project were:

- WP6 Scientific analysis for geotechnical applications: simulation and testing
- WP7 Scientific analysis for masonry applications: simulation and testing
- WP8 Diagnostic Tools and Methods for the Assessment of Structural Integrity
- WP9 Process/Technology Development and Applications guidelines
- WP10 Country Adaptation, Industrial Validation, and Contribution to Standardization
- WP12 Knowledge Management
- WP13 Training
- WP14 Dissemination
- WP15 Exploitation and IPR Management

Hereafter a brief description of the work performed within each of the above Work Packages is reported.

3.2 WP6: Scientific analysis for geotechnical applications: simulation and testing

Partners involved: UNI-KASSEL, DAPP, LS, IRIDEX, Safibra, Gloetzl, BAM, SMARTEC

Testing of a filter mat, the "long box" test, SMARTEC smart profile geogrid, and the "square box" test at Uni-Kassel

Work Package Objective: The objective of the WP6 is to investigate and validate the end product of WP4 and WP5, i.e., optic fibre sensors integrated in geosynthetics (MultiFunctional Geosynthetics, MFG)) for geotechnical application.

The following activities related to the task of the WP6 have been done during the reporting period:
- ✓ Completion of Long Box Tests No. 4-5
- ✓ FE modeling of Long Box test
- ✓ FE modeling and instrumentation plan developed for field test
- ✓ Completion of field test has been started and well in progress

Progress during Month 37-46 by task:

T6.1: Experimental Investigations – small scale model test

Small scale testing of project sensor-embedded geotextiles were completed during this last period Characterization of the mechanical properties and performance of the chemical sensor geotextiles have been conducted.

T6.3: Large Scale Model Test

Reporting on the two long-box model tests #4 and #5 was completed.
The major outcome from long-box model tests can be summarized as follows, referring to Geotextiles sensors:
- the SMARTube sensor, integrated in Filter-mat and non-integrated, was able to detect and localize heave correctly;
- Performance in terms of soil-sensor strain transfer and sensitivity can be obtained for Integrated SMARTube;
- Performance in terms of soil-sensor strain transfer and sensitivity can be obtained for non-integrated SMARTube;
- Integrated SMARTube presents higher sensitivity, due to the fact that the filter-mat is able to transfer strain on the whole length of the sensor;
- Integrated SMARTube has lower initial sensitivity, but once "activated" becomes more sensitive than non-integrated SMARTube;
- The linear behaviour shown by SMARTube in both tests allows making quantitative analysis of the acquired data.
- For the Deichkabel, the same considerations made for the SMARTube can be applied

Although it measures point-wise, the FBG sensor reacted very well to the incremental inflation and provided realistic strain values at the position of the lifting bag. The limitation of the FBG sensors is that they can only sustain a tensile strain up to 1.5%, which is very small for geotechnical applications.

Finally, these series of considerations comes from Task 6.3:

- Some polymer optical fibre sensors exhibited losses prior to the installation in the model box. These losses were caused by local bends of the fibres in the textile. The integration has been improved in the course of a series of tests;
- The integration of the glass optical fibre sensors with geosynthetics is good, especially with geogrids;
- The interaction of the MFGs with the soil was excellent;
- All optical fibre sensors with exception of few sensors are able to detect and localize the heave;
- All optical fibre sensors with exception of few sensors can provide a distribution of strain depending on the pressure applied;
- It is possible to measure a distributed high strains (6 % and more) with polymer optical fibres;
- The reference heave and strain measurements provide a good start point to verify the results of the OTDR or Brillouin measurements;
- The sensor that is not integrated in the filter-mat can easily slide inside the sand thus showing a lower sensitivity to vertical heave and shorter interaction length;
- All sensors also survived the extreme compaction and installation process;
- Based on the documented series of tests it was possible to select a sensor type and the integration with geosynthetics and recommend for field test.

T6.4: Numerical investigation, parametric studies, and interpretation of the results

DAPP concluded FE modelling of the long box test. After a long investigation involving different types of software, different type of solving approaches, different types of analysis, LS-Dyna was selected as the most suitable FE program due to its capability to easily simulate the lifting bag and the soil conditions. Deliverables 6.4 (numerical simulations of the experimental tests) and 6.5 (numerical parametric study) reports the results of the extensive numerical simulations campaign, while D6.6 provides an interpretation of the results achieved and guidelines for their adoption to the model prototype. The aim of D6.6 is to assess the effectiveness of the FE analysis and to support the interpretation of the laboratory tests at Uni-Kassel.
With this complete, the POLYTECT sensors have been validated by conventional sensors and a corresponding analysis program.

To expand the simulation and experimentation to real world scenarios in different types of soil conditions UNI-KASSEL proposed to test the Polytect products in a real application of field: a dismissed mining site at Zimmersrode in the vicinity of Kassel characterised by stability problems (soil sliding towards the lake formed in the old mining area) which needed some stabilisation works. In particular, it was decided to stabilise the area by large-scale removal of the unstable soil and replacement with more stable granular material. This required up to 8 m deep and 100 m long excavation works. POLYTECT materials have been recommended for use during this retrofitting activity specifically for the monitoring function. In preparation, UNI-KASSEL conducting an FE model of the area and identified the zone most appropriate for monitoring.

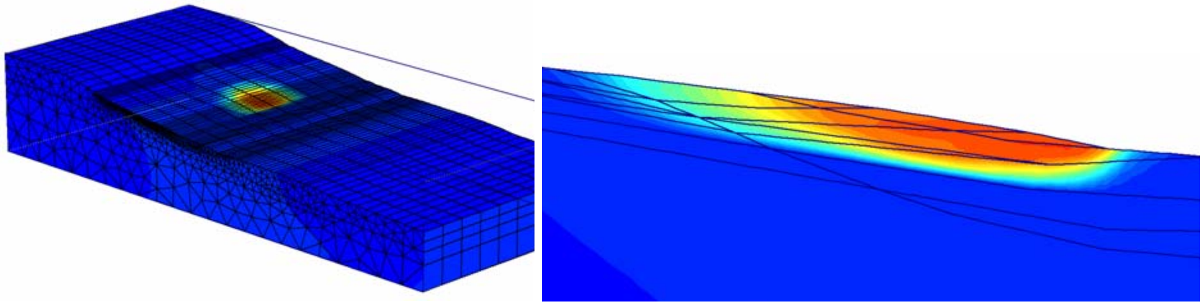


Figure 3.9: FE model of the failing slope area

Using this analysis, construction measures have been planned and sensor orientations proposed for the area of concern. The construction measure started end of July 2009 and were completed in March 2010.

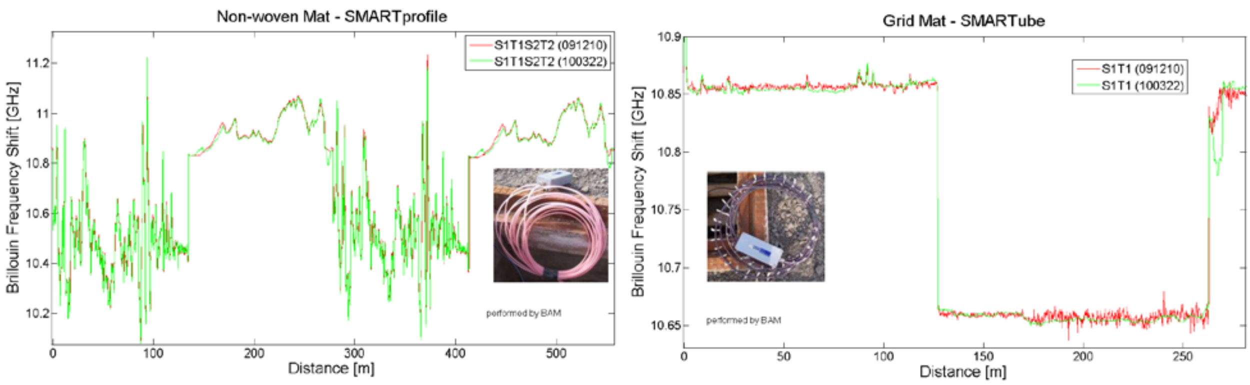


Figure 3.10: Comparison of the frequency shift in SMARTprofile (left) and in SMARTube (right) on 22.03.2010 and 10.12. 2009

3.3 WP7: Scientific analysis for masonry applications: simulation and testing

Partners Involved: **CETMA**, UKA, APC, BGP, DAPP, LS, Safibra, IMMG, BAM, STFI, IITMadras

Laboratory tests on small scale and large scale textile reinforced masonry walls at the University of Karlsruhe, Germany and at CETMA, Italy

Work Package Objective: The aim of WP7 is to perform scientific analysis for applications on the retrofitting of masonry structures. This is achieved through several sub-objectives:

- To select and optimize materials and application arrangements for retrofitting of masonry
- To evaluate and optimize the performances of the developed solutions for “smart” reinforcement of masonry structures
- To provide data to calibrate and validate integrated sensors, health monitoring and damage detection systems
- To collect expertise for development of design approaches and execution guidelines for retrofitting of masonry structures

Work Package Highlights Months 37-48

- Completion of Task 7.1 experimental campaign with the newly added feasibility study on sensorization of uniaxial, strip reinforcement;
- Completion of Task 7.2 with the building-up of last numerical models;
- Completion of Task 7.3 with the execution of last parametric analyses
- Un-reinforced and reinforced masonry building shaking table tests at IMMG;
- Reinforced stone building shaking table tests at the Eucentre;
- Completion of the numerical models;
- Interpretation of the results of the whole testing and numerical campaign;

Work Package Snapshot by Task and Deliverable

Tasks

T7.1: Experimental Investigations on small scale retrofitted structures
T7.2: Numerical Models
T7.3: Parametric studies on small scale retrofitted masonry structures
T7.4: Experimental investigation on real scale masonry structures
T7.5: Update of numerical models and parametric studies
T7.6: Interpretation and transfer of the results

Deliverables

D7.1 Optimization of fibre and adhesive materials
D7.2 Calibration and validation of integrated sensors
D7.3 Enhancement of strategies for the retrofitting applications on large masonry specimen
D7.4 Test results on small-scale retrofitted masonry structures
D7.5 Numerical tools for the analysis of retrofitted masonry structures

T7.1: Experimental Investigations on small scale retrofitted structures

Task 7.1 was completed during the first quarter of year four. It is the core of WP7 and consists of the testing of POLYTECT materials on different sizes and configurations of masonry structures.

The work in the last period was focused on Smart Patch Calibration. Cetma developing a model of structural element reinforced with a smart patch, in order to investigate on the effect of several geometric and mechanic parameters on the reinforcing and stiffening (the latter not always acceptable) effect of the patch on the element.

T7.2: Numerical Models

The main topic of task 7.2 is the formulation of numerical models describing the mechanical mechanisms of the masonry components and the retrofitting materials. The analyses have been performed using finite element methods. Due to its material properties, masonry is a material with distinct directional properties. The mortar joints act as planes of weakness. The necessary level of accuracy and the required simplicity (to keep calculation time within a limit) affect the choice of a modelling strategy which are:

- Micro-modelling: brick units and mortar are modelled discretely
- Simplified Micro-modelling: modelling of the behaviour of mortar joint and unit-mortar interface is merged in the contact elements
- Macro-modelling: unit, mortar and interface are modelled as a homogeneous model

Development of masonry simplified micro-model
A simplified micro-model was developed at KIT. The combined behaviour of joint and interactions between mortar and unit was modelled in user specified interaction behaviour in Abaqus using the UINTER interface for user defined material behaviour.

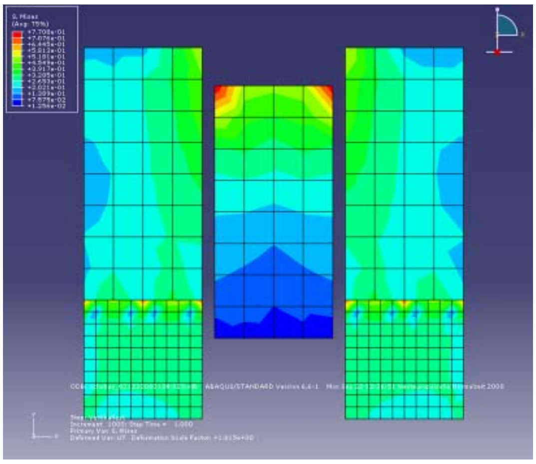


Figure 3.13. FE Modelling using a simplified micro-modelling strategy

Development of composite macro-model:
DAPP developed macro-models suitable for simulating the textile applied on the masonry walls to be a strong supporting element in comparison to the experimental results of the laboratory and field tests. An equivalent shell element that represents a uni-axial as well as a quadric-axial textile has been developed. Shell elements allow modeling one face reinforcement, overlapping reinforcement, and wrapping reinforcement. The large, small, medium, and Polymast tests (shaking table tests of 2 storey masonry building) gave reasonable data with which this approach has been calibrated.

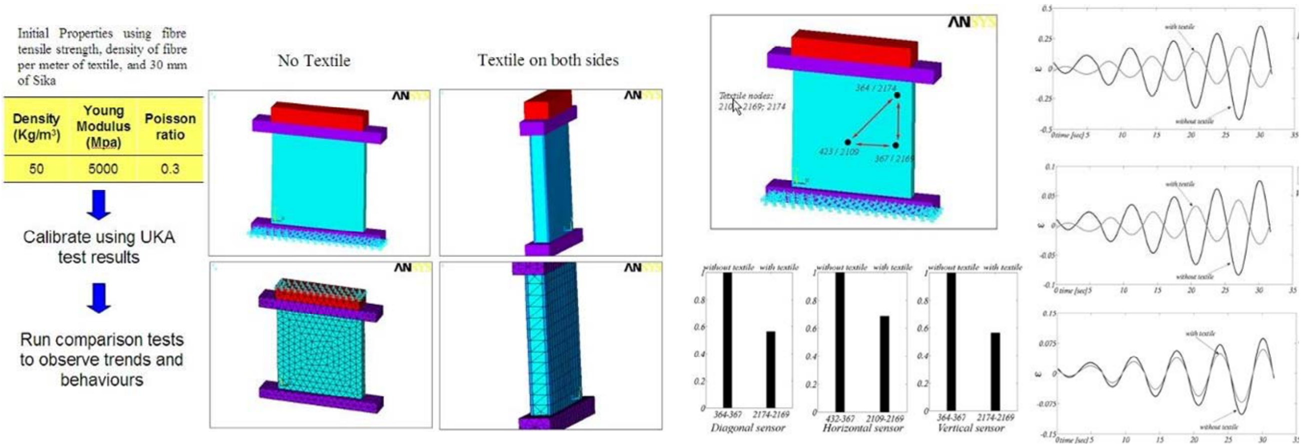


Figure 3.14. DAPP modelling and initial results

Development of a macro-model of masonry:
IIT Madras developed a macro-model for masonry structures to help in modeling the building tested on shaking table tests for WP10. The finite element software ABAQUS 6.8 was used for the modal analysis. In fact, Abaqus offers a wide range of capabilities for simulation of linear and nonlinear applications. Problems with multiple components are modeled by associating the geometry defining each component with the appropriate material models and specifying component interactions.
The functions "umat" and "vumat" were used for the implementation of user defined materials, while the function "uinter" was used for the formulation of special interface behaviour (as it is that in between bricks and mortar).

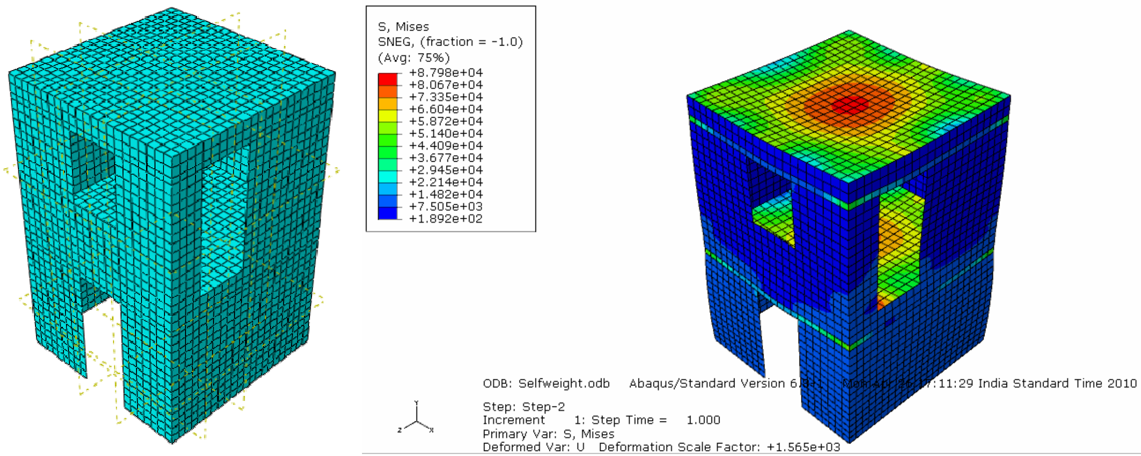


Figure 3.15: Meshed two storey unreinforced masonry structure (left); Von Mises stress (right)

Development of structural models to interpret the information from sensors
Aside from the modelling complexities of being able to simulate correctly the complex masonry failure behaviour, a critical task is the correlation of sensor measurements with the structural behaviour of masonry structures. To this end, KIT in collaboration with DAPP and CETMA have been developing and discussing the concept of "Seismic Wallpaper". The idea is to consider the textile covering as a skin that can provide the strengthening and monitoring functions for the structural health assessment. In doing this, a deliberate and important decision must be taken on the orientation of the sensors embedded into the textiles. Using sensor-embedded textiles, sensors can reasonably run up and down the structure, across a structure, or diagonally. Depending on material properties (specifically stiffness), a wall or structure can behave rigid, flexible, or semi-rigid. This behaviour will determine what orientation is optimal for the sensor orientation. 2D and 3D FEM of

the IMMG shake table test was conducted to compare expected sensor sensitivities with respect to their orientation.

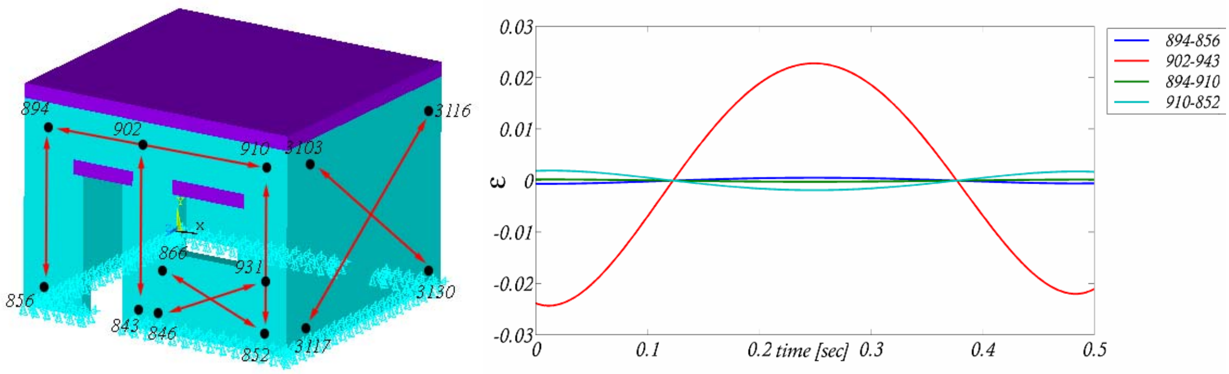


Figure 3.18: 3D walls models. Examples of deformation during time of critical lines for the diagonal critical lines, representing different possible sensors locations

T7.3: Parametric Studies

In general, parametric studies can be framed in terms of both experimental (different sized walls, mortars, etc) and modelling (one/two story, etc) study, although the latter is usually less expensive.
In terms of numerical modelling, it's worth to point out the high complexity of modelling of masonry structures. These structures are non-homogeneous and a deliberate decision must be taken with respect to modelling the mortar-brick interaction. Furthermore, different sized structures behave differently. POLYTECT introduces two new variables into this challenge. These are:

- The properties and behaviour of the adhesive compound utilized to attach the textile to the structure
- The properties and behaviour of the reinforcing textiles.

Task 7.3 is dedicated to the study of varying these parameters to better understand the importance of each on the structural behaviour. The following parameters have been numerically analysed with reference to building behaviour:

- Number of storeys;
- Vertical and horizontal geometry
- Mass;
- Type of earthquake loading
- - Type of reinforcing solutions (full coverage vs. strip coverage)

Some results of these studies are reported below with reference to the number of story and the structural symmetry of the models.

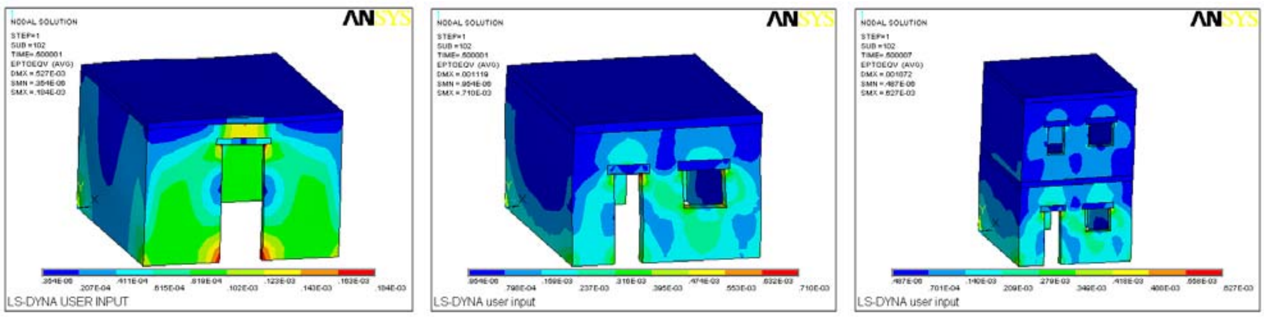


Figure 3.20: Von Mises strain distribution from dynamic analysis: single story buildings (symmetric and non-symmetric) and two-story building

With reference to the behavior of un-reinforced structures vs. reinforced structures, some parametric studies have been conducted, accounting for strips and full-cover reinforcing solution. A reduction of the strains values due to GFRP composite material was observed. Finally, the effectiveness of the reinforcement and the best location and orientation of sensors was demonstrated taking as example the building model tested on the shaking table in Pavia. The following figure shows the values of the normalized maximum peak strain for both the unreinforced and reinforced building model, with reference to the maximum strain value of the un-reinforced building for each of “the lines” investigated.

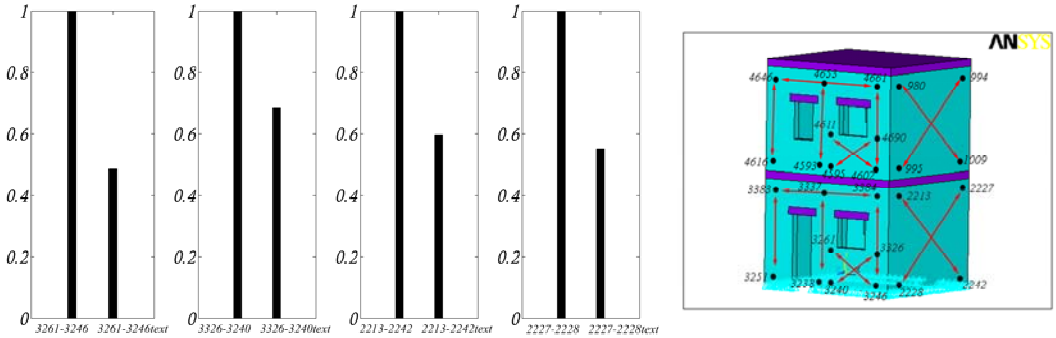


Figure 3.23: Normalized maximum strain values for both the un-reinforced (left of each plot) and the reinforced (right of each plot) building

T7.4: Experimental investigation on real scale masonry structures

Shaking Table Tests at IMMG

During the last year of Polytect, two shaking table tests have been carried out at IMMG. The “Polytect Building 3” was constructed and tested un-reinforced in November 2009. It was then repaired and re-tested reinforced with GFRP (using epoxy resin) on January 2010. Numerical analyses and experimental dynamics characterization have been carried out and presented in WP8. The two shaking table tests together with numerical simulations and experimental dynamic tests allowed a deeper comparison of the performance of the uni-axial textile (UNI-410 - Selcom made) for the strips reinforcement of masonry buildings and of the Fiber Bragg Grating (FBG) sensors embedded.

The building shape is typical of masonry buildings in the Greece countryside. It consists of four single brick walls, with doors (in the walls orthogonal to the seismic action direction) and windows (in the walls parallel to the seismic action direction). A reinforced concrete roof (319 cm x 278 cm x 10 cm) is placed at the top of the four masonry walls. Reports from IMMG present the building materials, analysis of measurements, numerical predictions and building performance under extensive seismic loading.

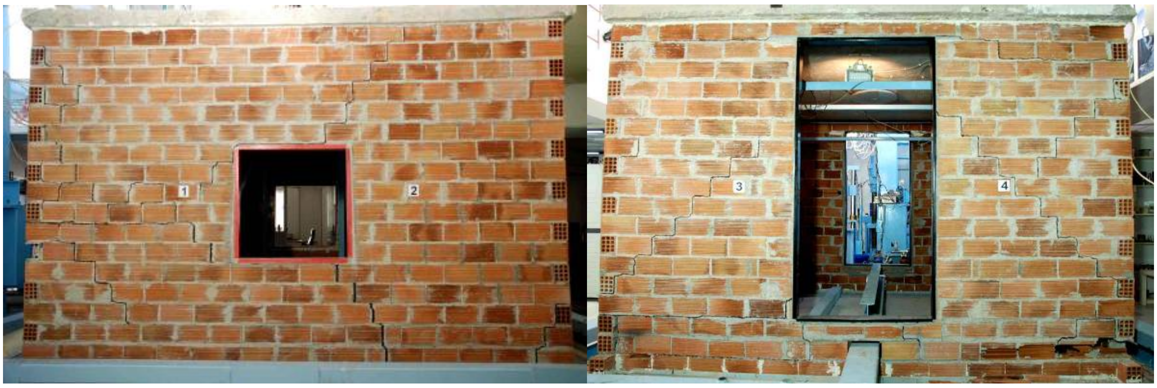


Figure 3.24: The masonry building damaged after the application of seven compatible to EC8 accelerograms (ag=0,15g): walls 1 and 2 (left), walls 2 and 3 (right)

Figure 3.25: The building as reinforced with striped uni-axial textiles. Walls 1 and 2 (left) and 3 and 4 (right)

More than any possible comments and interpretation, the plots of the crack patterns given below document the benefit of the strips reinforcing for masonry structures like the one tested at IMMG (i.e. very stiff). This result is one of the major outcomes achieved by WP7 in the last project year.

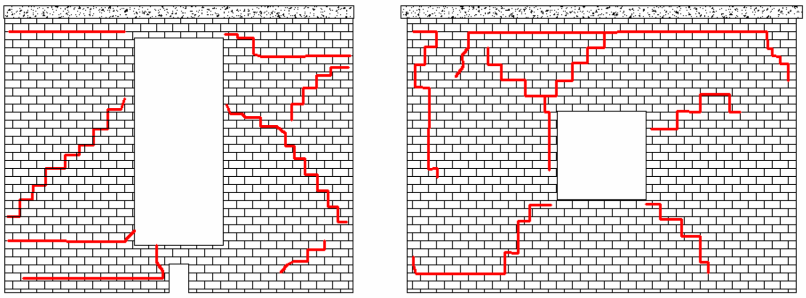


Figure 3.27: Crack patterns of the un-reinforced building after the strongest shaking table test

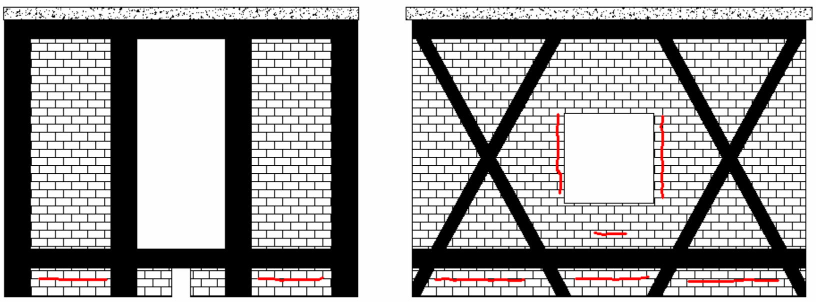


Figure 3.28: Crack patterns of the reinforced building after the strongest shaking table test (more then 2 times stronger than the one referred to for the un-reinforced building)

It is worth noting that numerical simulations were conducted to confirm the results deducted from the experimental tests.

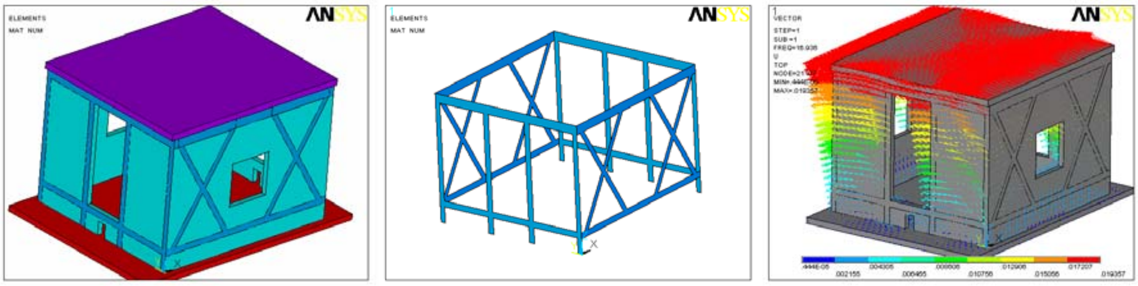


Figure 3.30: Numerical simulations of the reinforced building: FE model (left); modal analysis (right)

T7.5: Update of numerical models and parametric studies

Each partner developing numerical models in Task 7.2 and 7.3 is using results from the experimental tests to calibrate and improve those models. For D'Appolonia, this entails the improvement of the equivalent textile shell element. For IIT Madras, the first FE model developed at IIT-Madras to analyze masonry panels with GFRP reinforcement underwent a first updating using, as materials input data for masonry, mortar and GFRP, the figures obtained by testing. A further update is being performed on the basis of the experimental results of the corresponding mid-scale test on reinforced masonry wall. Lastly, Cetma worked on the updating of the model of structural element reinforced with a smart patch, calibrating the model on the basis of the experimental data obtained in the tests performed at KIT. Deliverable 7.5 reports the updates of the FE models conceived within Polytect and explore the basic formulations which are behind any of these solutions, with reference to the elements formulations for masonry bricks (Solid elements) and textiles panels (Shell elements).

T7.6: Interpretation and transfer of the results

In this task a considerable amount of work was devoted to the interpretation, in function of the requirements set in WP1, of the results from previous tasks.

Global recording of test data is base of analysis of different important material properties. For example, recording of vertical displacement and horizontal shift of masonry members under **combined compression-shear load** is used to analyse the dilatancy of masonry. Especially in the post crack behaviour, the dilatancy seems to decrease on reinforced specimen.

Interpreting the results of the **tension tests on smart patches** in order to evaluate the possible degradation of mechanical properties due to sensor embedding, very useful information were obtained in view of the possible use for strengthening purpose also. In fact, taking also into account that in real applications the patch width will be higher than the one used for tensile coupons (so that the influence of defect will be lower) 12÷15% can be considered as an upper limit for property degradation, to be taken into account in patch design.

The interpretation, in terms of real case applicability, of the **FE results of the model of masonry reinforced with GFRP** led to the conclusion that the ultimate lateral strength and ductility can be increased by retrofitting the shear and flexure specimens with full surface bonding of GFRP composite fabric in a better way that with strip coverage.

A theoretical discussion was then carried out about the **interpretation of monitoring data from the sensorized textiles**, taking into account the constraints given by:

- Relative position and orientation of the sensor inside the textile

- Position and orientation of the textiles on the structure (depending on the textile type and the reinforcing strategies)

The discussion led to an outline of the possible information that can be obtained from the sensors embedded in quadriaxial textiles, for different textile orientations on the structure (vertical, horizontal or diagonal) and for different failure types. This discussion led also to the decision to perform a feasibility study on sensorization of uniaxial, strip reinforcement that can be used for many applications (shear and out-of-plane bending of walls, compression of columns etc.).

The interpretations of the numerical parametric studies of Task 7.3 led to the formulation of guidelines for sensors locations, for reinforcement strategies and for implications of any reinforcing solutions. With reference to the three typologies of masonry buildings accounted for in the FE simulations the following considerations may be achieved and may be transferred to the shaking table tests conducted in Pavia and at IIT Madras in WP10.

One story symmetric building
The reinforcement should be striped:

- Diagonal close to the openings
- Vertical at the edges of the walls with openings
- Diagonal on the walls without openings.

One story non-symmetric building
The reinforcement should be striped:

- Diagonal under the windows and from the top of the doors to the bottom of the windows;
- Vertical close to the doors side, in such a way to constrain the openings and to confine them.

The reinforcement is able to strongly reduce displacements, stress and strain values of localized critical areas of the building, but also is able to provide an uniform reduction of strains in different areas: A full-coverage solution can also be considered

Two stories non-symmetric building
The reinforcement should account for vertical and diagonal strips

- Diagonal reinforcement under the first floor and the second floor windows and from the top of the doors to the bottom of the windows (for the first floor) and from the top of the longer windows to the bottom of the smaller windows for the second floor;
- Vertical reinforcement close to the doors sides at the first floor and close to the longer windows at the second floor. The effect will be here mainly of confining the bigger openings of the building.

The reinforcement can be a full-coverage solution as both diagonal and vertical areas deformation are strongly reduced in each considered locations of the building surface (i.e., the full-coverage solution is able to uniform reduce strains on the building surfaces). This solution seems to be the most favourable for reinforcing masonry buildings of the type of those considered in the numerical models.

Finally, study and interpretation of the sensor data in **shaking table test** allow the following remarks:

- The FBG sensor shows promise to give early warning of later structural damage;
- The FBG sensor is able to record the seismic signal;
- The FBG sensor deformation "steps" correspond in time to seismic events recorded on other FBG sensors (which do not show evidence of deformation);
- Detection limit is at micrometer size cracks;

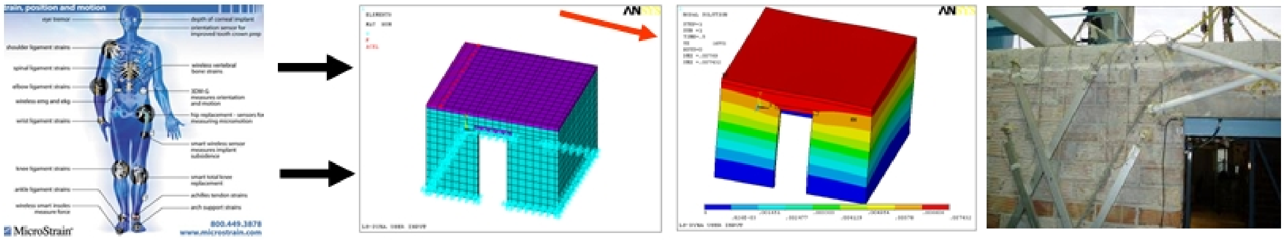
- The importance of selecting an adequate sensor lay-out on the basis of the expected structural behaviour is stressed;
- The large shift in some strain signal definitely indicate that there has been some deformation of the structure (cracks opening) in the area. The inability of the same sensor to pick up a seismic signal may be:
  a) an indication that the vibration mode of the building has changed
  b) an indication that that the block at which the sensor is mounted on is decoupled from the rest of the building (and building therefore has a major structural damage)
  c) a sensor fault.

At the moment too little information is available to discriminate among these three possibilities; nevertheless, if (b) is a possible explanation, then it can be said that dynamic strain measurements on the buildings could be used as a damage assessment method (i.e. correlating the response at different parts of the building before/after event during aftershocks).

3.4 WP8: Diagnostic Tools and Methods for the Assessment of Structural Integrity

<u>Research Partners: UKA, UNI-KASSEL, IMMG, CETMA, UCM</u>

<u>Industrial Partners: DAPP, APC, LS, SAFIBRA</u>



<u>Work Package Objective</u>: The objectives of WP8 are

- to investigate and define the health monitoring techniques appropriate for POLYTECT applications, products, and sensors
- to develop a methodology for monitoring the onset of structural damage, assessing the safety of constructions, and capturing building performance, using distributed textile sensors
- to understand effects of boundary conditions and ambience on health monitoring
- to perform integrity monitoring on large scale and full-scale structures

<u>Work Package Highlights Months 37-48</u>

- ✓ Development of tools and analytical approaches for the damage detection in masonry structures by means of fiber optic sensors data
- ✓ SHM techniques specific to dynamic measurements
- ✓ Statistical analysis SHM of the Villa Reale in Monza, Italy conducted with respect to temperature and displacement

<u>Work Package Snapshot by Task and Deliverable</u>

<u>Tasks</u>

T8.1: Definition of the health monitoring techniques appropriate for POLYTECT applications, products, and sensors
T8.2: Definition of a methodology for damage detection using distributed textile sensors
T8.3: Analysis of variance of results to boundary and ambient conditions
T8.4: Validation and demonstration

<u>Deliverables</u>

D8.1. Definition of diagnostic tools and methods appropriate for POLYTECT applications, products, and sensors
D8.2: Definition of a methodology for damage detection using distributed textile sensors

T8.1 Definition of the health monitoring techniques appropriate for POLYTECT applications, products, and sensors

WP8 partners participated widely in the major SHM conference of the period (September 2009 - August 2010), the 5th European Workshop in Structural Health Monitoring.

Based on the main outcomes from this conference, Polytect decided to continue the investigation on:

- Definition of critical thresholds for masonry buildings subjected to dynamic excitations;
- Statistical Methods to detect the changes in trends of the measured data from FBG sensors
- Experimental Modal Analysis (EMA) techniques from FBG sensors data
- Damage detection techniques

All the aforementioned aspects accomplished the development of a Finite Element Structural Monitoring (FESM) method. This means the correlation of numerical and experimental which became the dual faces of the same approach for monitoring techniques. In fact FE results can be considered to:

- predict the building behavior in terms of modal parameters;
- validate the reinforcing solution by means of dynamic non-linear analyses,
- help in choosing a preferable sensors topology (i.e., number and locations of sensors);
- constitute a reference case for comparison with experimental results (i.e., fiber optics sensors measurements records) in both time (for seismic loads) and frequency domain.

while experimental results allow to:

- asses the stress-strain correlation for the masonry elements of a building after a seismic event;
- identify the building dynamics and the variation of its modal parameters to assist in damage detection.

The IMMG and the Eucentre tests were chosen as case studies towards the implementation of such strategies and the validation of the performance of FBG sensors to detect the dynamics of masonry buildings, to assess damage and the consequent structural integrity of the structure.

Detection of deformations for subsequent events

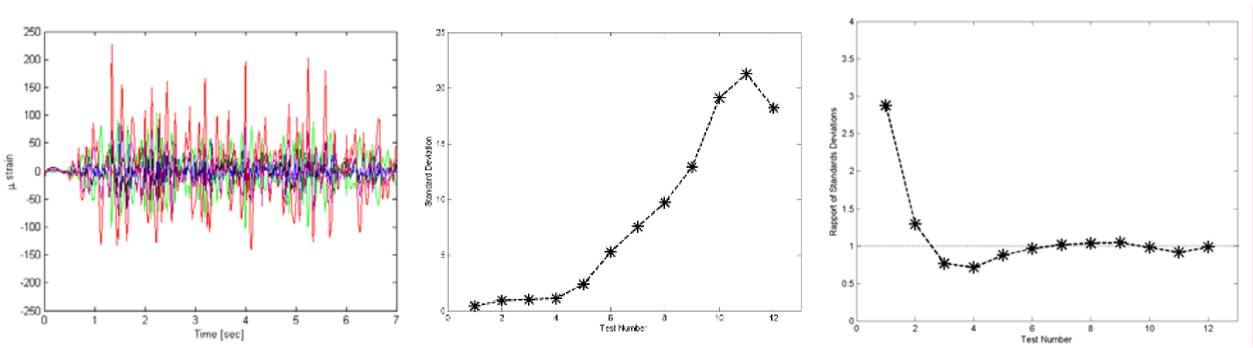


Figure 3.33: Data processing from FBG sensors during seismic events (IMMG tests): deformation time history (left); standard deviation (SD) of recorded deformations (middle); ratio of SD for different sensors in close locations (right)

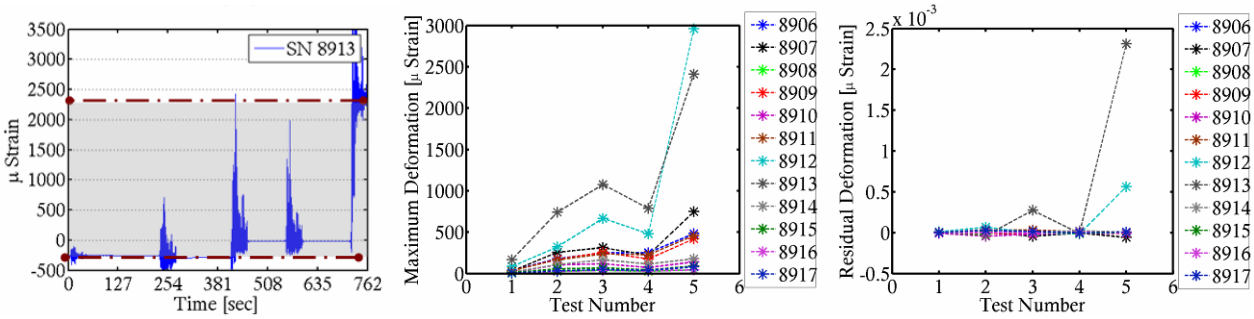


Figure 3.34: Data processing from FBG sensors during seismic events (Eucentre tests): deformation time history (left); maximum deformations (middle); detected plastic deformations (right)

T8.2 Definition of a methodology for damage detection or stiffness enhancement using distributed textile sensors

The definition of a methodology for damge detection using fiber optics sensors is detailed in D8.1 and is tested on the data of IMMG (D8.2) and Eucentre testing campaign.
A frequency-based damage technique allows, within any system dynamics identification scheme, determining in a very fast and efficient way, in any environmental condition and without the need of long computational analysis, if damage is occurring elsewhere in the structure and if a retrofitting of the building (due to excessive variation of its resonant natural frequencies) is needed.
For these reasons of effectiveness and clearness the method was adopted for determining if cracks occurred in a masonry un-reinforced building while it was experimentally tested under seismic loads. In fact, this method also allows defining in real-time (i.e. after each experimental seismic events) the damage conditions of the structure by looking at the variation of its natural frequencies in X, Y, Z calculated by a Fourier Transform of the signals recorded by accelerometers sensors during each test. From the information achieved in terms of correlation between frequencies variation and cracks propagations, it is possible to decide when the structure is close to its ultimate state (i.e. the collapse) and to define any suitable retrofitting solution to strengthen it.
Examples of the information achievable by means of a frequency-based damage technique linked with EMA results and the applications of system identification methods, such as the Eigensystem Realization Algorithm, are given below.

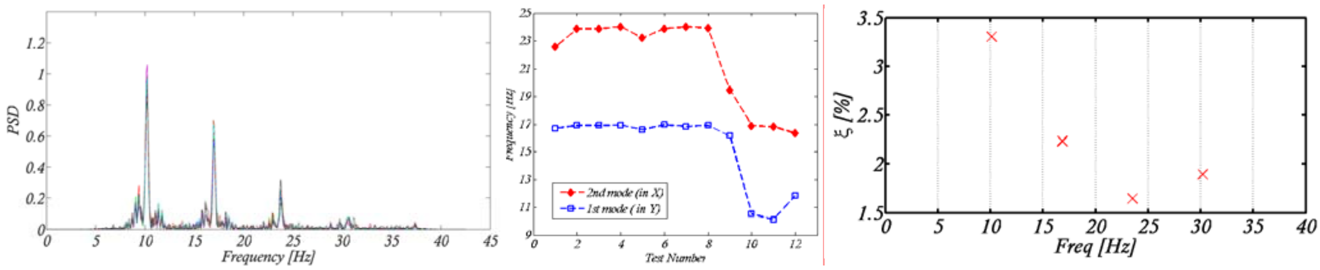


Figure 3.35: Frequency domain analysis of the FBG sensors data recorded during forced vibration tests (IMMG): Power Spectral Density function (left); frequency variation vs. seismic events (middle); identified natural frequencies vs. identified damping ratio (right)

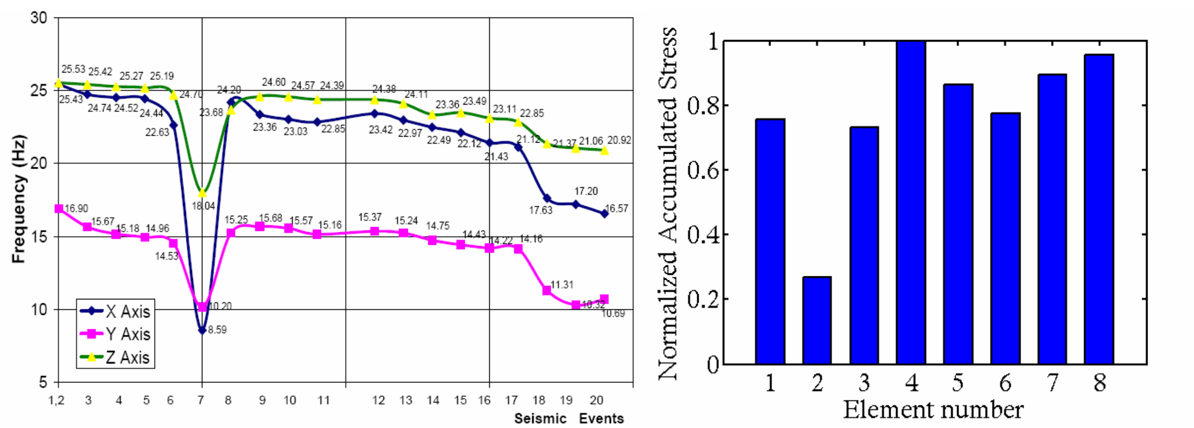


Figure 3.36: Natural frequencies variation at IMMG from un-reinforced to reinforced building from standard accelerometers sensors (left); corresponding Damage Location Vector (DLV) method plot for critical masonry elements in the vicinity of FBG sensors at test n°18

From the IMMG tests, with respect to a methodology for structural integrity detection, it can be pointed out that:

- ➢ FBG sensors can collect data to characterize structural performance over time
- ➢ FBG are able to capture and record data the stress/strain variation on the structure during seismic events

- FBG allow to identify the buildings dynamics trough experimental analyses

From the Eucentre tests, with respect to a methodology for structural integrity detection, it can be pointed out that:

- sensors placed in key locations (close to a forcing point) are able to record the structural response in terms of axial deformations;
- from the measurements recorded by FBG sensors EMA can been carried on to detect the building natural frequency in X and Y;
- the adoption of the ERA method (functional when an impulse force is applied to the structure) is suitable for characterizing the building dynamics and modal parameters (frequency, damping, mode shape);
- by reconstructing the flexibility matrix from the FBG sensors measurements, the location of damage is feasible.

Task 8.3 Analysis of the variance of results with respect to environmental effects

The Analysis of the variance results with respect to the environmental effects has its core case in the study of the long term behaviour of structural members in the Villa Reale located in Monza, Italy. D’Appolonia (sensor interpretation) and Smartec (sensors installation) were directly involved in this investigation.

SMARTEC D'APPOLONIA

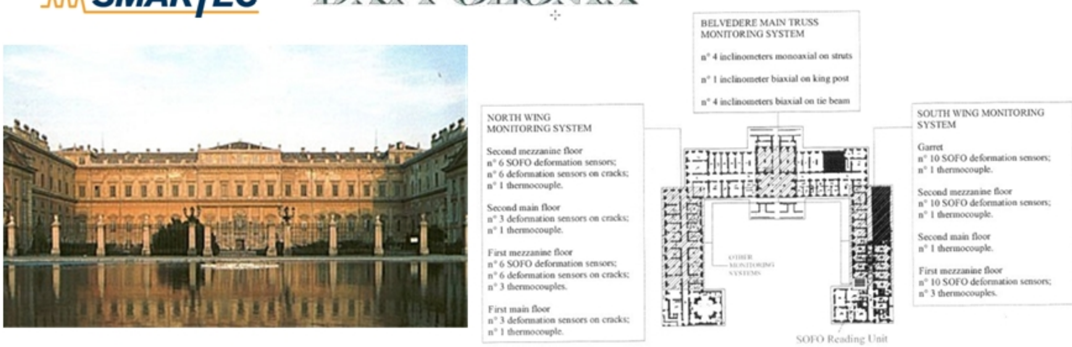


Figure 3.39: Villa Reale and sensor layout, Monza, Italy

This structure underwent retrofit because its walls were drifting apart causing major cracking due to uneven ground settlements. Strain and temperature sensors that take readings every 4 hours were employed to monitor the structure before and after retrofit providing a rich statistical database. These measurements are being studied to observe the correlations between temperature and displacement over daily and seasonal cycles. If these correlations change, it may indicate damage. This data normalization procedure, even if not exhaustive, is important to document the history of the structure over time.

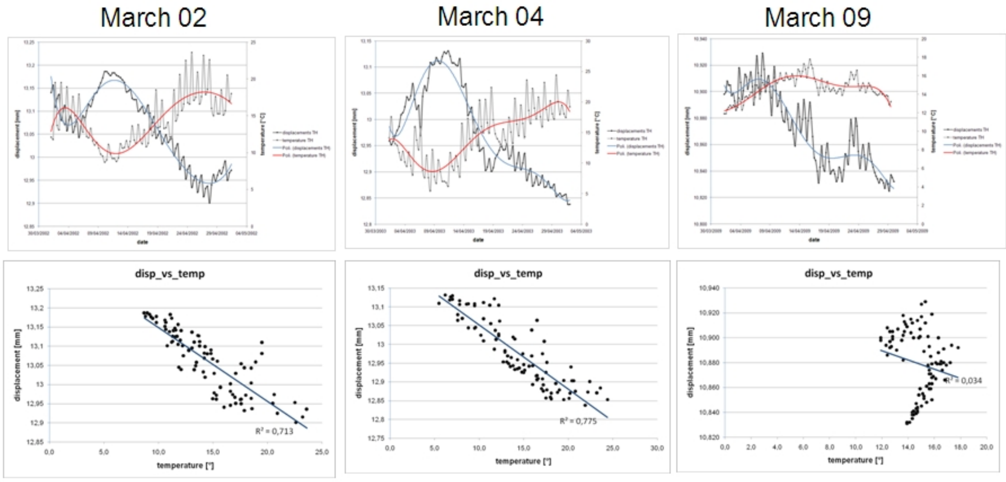


Figure 3.40:Temperature-displacement correlations over time for one sensor at the Villa Reale

3.5 WP9: Process/Technology Development and Applications guidelines

<u>Research Partners: STFI, CETMA</u>

<u>Industrial Partners: SLS, Extreme, Karl Mayer Malimo, SELCOM, Safibra</u>

Work Package Objective: The objectives of WP9 are

- to define manufacturing/process adaptation
- to develop a suitable quality assessment procedure
- to provide application guidelines

Work Package Highlights Months 37-48

- ✓ WP9 Kicks Off at M37
- ✓ Realization and completion of Task 9.1, 9.2 and 9.3

Work Package Snapshot by Task and Deliverable

<u>Tasks</u>

T9.1 Manufacturing/process adaptation
T9.2 Quality procedures definition and implementation
T9.3 Application guidelines definition and implementation

<u>Deliverables</u>

D9.1: Manufacturing process description
D9.2: Quality procedures
D9.3: Application guidelines

Progress by Task M37-M48

T9.1 Manufacturing/process adaptation

T9.1 addressed the adaptation of machinery for and the manufacturing process update for rope-like textiles and for plane fabric structures.

The main technical outputs achieved during year 4 are summarized in what follows:

- Optimised Processing for Kemafil® technology and principal design of different rope-like structures with sensors integration;
- Optimised Processing for rope-like Braiding technology and principal design of different rope-like structures with sensor integration or tube integration;
- Optimised Processing for tape-like technology and principal design of different tape-like structures with sensors integration;
- Manufacturing process update for plane fabric structures.

Figure 3.41: Overview Braiding Technology

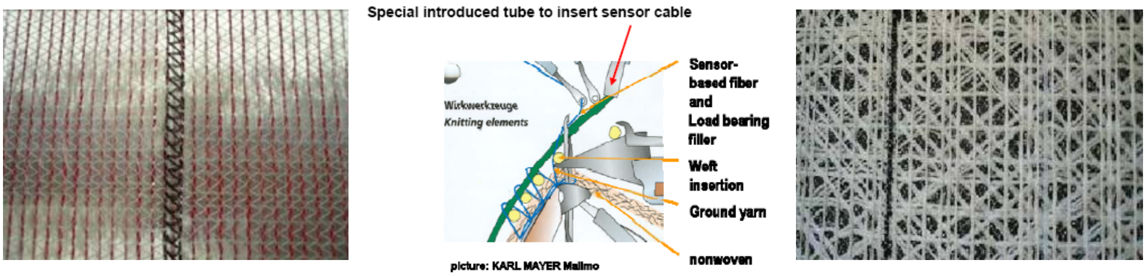


Figure 3.42: Examples of textile fabrics (left and right); Special introduced tube to insert sensor cable (middle)

T9.2 Quality procedures definition and implementation

T9.2 addressed the testing procedures definitions and implementations.
Within the frame of WP9, in Task9.2 the quality procedure for the developed textile sensor-integrated structures consist of the following components:

- Fibre optic sensors
- Multi-axial, warp-knitted, glass and/or polymer fibres
- Nanoparticle enhanced coatings for the textile fabric
- Nanoparticle enhanced mortar to bond the textile to the masonry structures
- An interrogation system to acquire data from the sensor-embedded textile-mortar composite

In Task 9.2 the following tests have been successfully conducted:

- tensile strength behaviour of fibre optic sensors
- tensile strength behaviour of bi- and multi-axial warp-knitted structures
- tensile strength behaviour of bi- and multi-axial warp-knitted structures with integrated sensors
- shearing behaviour for the textile structures used in composites
- shearing behaviour for developed nanoparticle based enhanced mortar to bond the textile to the masonry structures
- functionality and calibration of interrogation system to acquire data from the sensor-embedded textile and/or composite while tensile testing

From the results of all tests it can be stated that all samples of developed geotextiles within the PolyTect project fulfilled the highest robustness class for geosynthetics according to the current standards. The long-term behaviour of such geosynthetics has been stated for at least 20 to 50 years. However, the sensor measuring capability over such long period of time needs further investigation for real application in infrastructure to ensure current safety factors.

The masonry sensor-integrated textiles show a highly improved ductile behaviour in tensile tests which allow the use each material property to its full extend and safe the full construction in case of damage.

Figure 3.43: Examples of testing procedure: net test (left) and tensile strength (right)

T9.3 Application guidelines definition and implementation

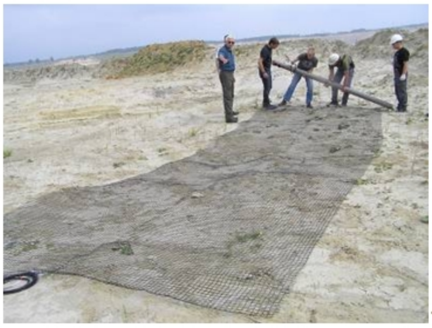
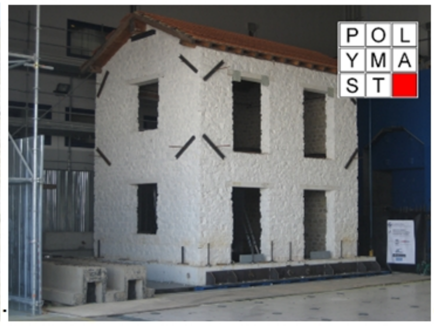
T9.3 focused on handling specifications of material at processing, transportation, and installation at building sites.

The main actions carried on within Task 9.3 during the 4th of the project are related to application guidelines definition and implementation to define the handling specifications for the material and prototypes developed within the project concerning processing, packaging & transportation to building site. The deliverable D9.3 “Application guidelines” reflects the summary of all experiences made while executive research into the single steps of processing and first field tests for the targeted applications. Guidelines for textile processing as well as for composite processing have been produced by this task.

3.6 WP10: Country Adaptation, Industrial Validation, and Contribution to Standardization

<u>Research Partners: KIT, UNI-KASSEL, IMMG, CETMA, UCM</u>

<u>Industrial Partners: DAPP, APC, LS, SAFIBRA</u>

<u>Work Package Objective</u>: The objectives of WP10 are

- to define guidelines and instruction for industrial application
- to select test cases for demonstration
- to provide Demonstration and Validation
- to provide Contribution to Standardisation

<u>Work Package Highlights Months 37-48</u>

- ✓ Masonry field test at EUCENTRE, Pavia (Italy)
- ✓ Masonry field test at IMMG, Athens (Greece)
- ✓ Geotechnical field tests conducted at Zimmernode (Germany)
- ✓ Geotechnical field tests conducted at Belchatow (Poland)
- ✓ Chemical field tests conducted at Albota landfill (Romania)

<u>Work Package Snapshot by Task and Deliverable</u>

<u>Tasks</u>

T10.1 Guidelines and instructions for industrial application
T10.2 Demonstration and Validation
T10.3 Analysis of applicability of project results to other sectors than construction
T10.4 Standardisation

<u>Deliverables</u>

D10.1: Guidelines and instruction for industrial applications
D10.2: Demonstration and Validation
D10.3: Standardisation document

<u>Progress by Task M37-M48</u>

T10.1 Guidelines and instructions for industrial application

Task T10.1 is one of the key activities to move Polytect form the level of a research project to the industrial market. The aim which is highlighted in D10.1 is to provide guidelines, instructions, and

recommendations for the application of the multifunctional textiles developed in the project in the construction sector for the envisaged applications, namely for the reinforcement of masonry structures against seismic loadings and for stabilisation and monitoring of geotechnical works. Guidelines and recommendations have been drafted as a result of the field test activities developed within WP10 “Country adaptation, Industrial Validation, Contribution to Standardisation”, where practical applications of the multifunctional textiles have been carried out.
In particular the following actions have been conducted and reported in D10.1:

- application of the Polytect Multi-functional textiles for the reinforcement of masonry structures;
- applications of the Polytect Multi-functional Geotextiles (MFG) for geotechnical works

Referring to the first topic some key elements are:

- The preparation of the substratum for the textile application;
- The surface treatments of the substratum for the textile application;
- The adaptation of textile insertion in corner area;
- The sensors insertion inside tubes and their protection;

Figure 3.45: Preparation of the substratum (left), Application of a first layer (middle), Application of an epoxy resin layer (right)

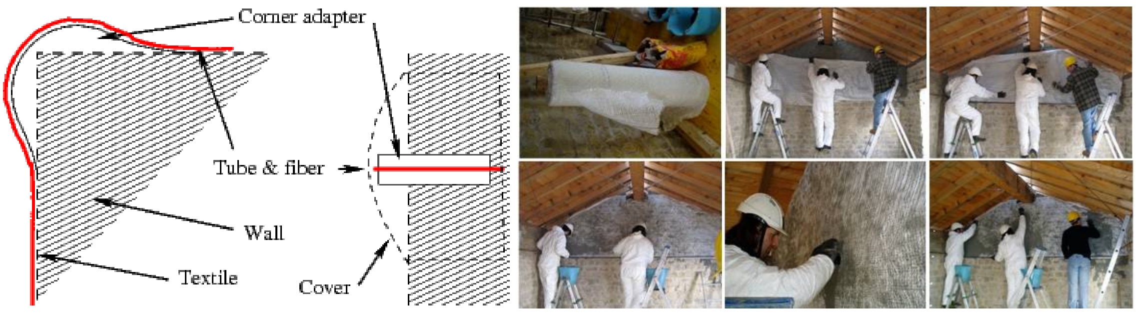


Figure 3.46: Adaptation of textile in corner area (left); textile application on a wall surface (right)

Referring to the second topic some key elements are:

- Subgrade preparation;
- Product installation;
- Tensioning and fixing the geotextiles;
- Protecting the geotextiles and the integrated sensors.

Figure 3.47:Multi-functional geotextile application steps

T10.2 Demonstration and Validation

Field tests have been completed during the last year of the project. The results from these field tests have been published in scientific papers, have been an important dissemination tool, and have provided the basis to support the other tasks (guidelines, applicability, and standardization procedures).

The field test activities have comprised the demonstration of the developed multifunctional textiles for the reinforcement and monitoring of two kinds of structures: masonry structures, for seismic upgrading or structural retrofitting, and earthwork structures where geotextiles are used for the stabilisation of the substrate and the redistribution of the internal stresses or for consolidation.

In each field test the multifunctional textile concepts developed in previous WPs have been used, by selection the most suitable for the application under study among the various configurations available in terms of materials composition and textile architecture. The demonstration work has been carried out in such a way to utilize the advanced multifunctional textiles derived from the previous WPs of the Project, for both strengthening and monitoring purposes.

Field tests conducted within Polytect comprise the following:

- Chemnitz Railhead (Geotechnical: settlement)
- Belchatow (Geotechnical: slope stability)
- Zimmersrode (Geotechnical: repair assessment)
- Albota Landfill (Chemical Monitoring)
- IMMG shake table testing (Masonry: reinforcement and damage detection)
- Eucentre-Polymast (Masonry: reinforcement and damage detection)
- IIT Madras shaking table testing (Masonry: reinforcement and damage detection)

Figure 3.48:Chemitz Railhead MFG (left), railway site (right)

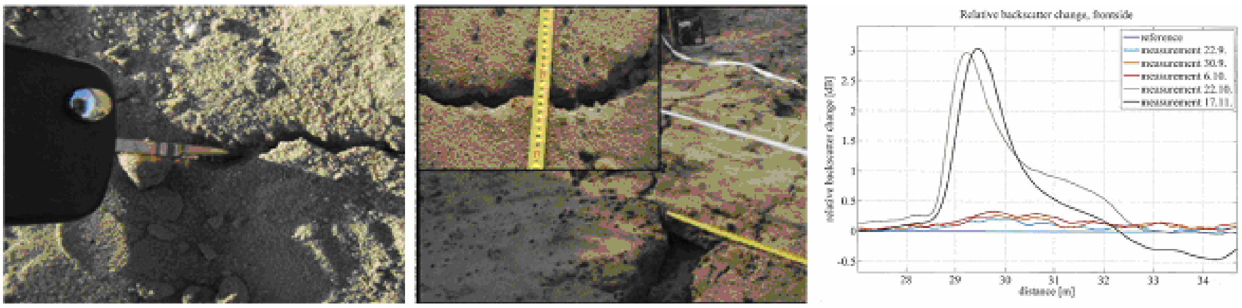


Figure 3.49:Belchatov creeping assessment by MFG sensor (right)

Figure 3.50: Zimmersrode MFG installation

Figure 3.51: Albota Landfill Chemical Sensor Installation

Figure 3.52: IMMG strips reinforcement by multifunctional uni-axial textile

Figure 3.53: Eucentre-Polymast full-cover textile reinforcement: mortar + textile as they look like when applied to the wall (left); the building full cover after some days (right)

Figure 3.53:IIT Madras masonry building: un-reinforced (left); strips reinforced (right)

T10.3 Analysis of applicability of project results to other sectors than construction

The activities of demonstration carried out within the Polytect project were a complete success as demonstrated by the number of field tests and their quality. Field tests of the textile products for geotechnical applications have taken the opportunity of application of the materials in real works under real and different working conditions.

The lessons learned from the field tests are extremely useful for the future applications of the POLYTECT materials and as elements for their commercial exploitation in other construction sectors. A sector of particular interest is the one of composite vessels. For tanks, containers, and vessels inspection methods are archaic: the tank has to be emptied and cleaned, hazardous liquids must be transported to alternative tanks, workers enter into the tanks risking chemical contact and inhalation exposure. In view of these risks and associated costs, the trend in inspection R&D is to develop non-invasive detection techniques combined with robots that take measurements from the inside of the tank. Efforts in the laboratory have also investigated the layup of fibre optics to the outside of vessels and containers as shown in the following figure.

Figure 3.54:application of multifunctional textiles for leaks detection in composite vessels

Challenges identified include sensor breakage, the care and time required for manual layup, and microbending of the fibre optic signals. With respect to operation, sensors are being added to tanks and vessels. Simple wireless sensors that measure container content (such as at filling stations) are being utilized (as add on solutions) to realise “on time” refilling instead of scheduled refilling saving significant logistics resources. With respect to incident response the approach (pumping out contaminants and pumping in clean water) is necessary but the logic is incorrect. The leak needs to be detected and remediated at its onset while the leak it is still in the tank.

Sensor-embedded textiles acting as skins and barriers can decisively improve tank Inspection, Operation, and Incident Response. How? By acting as a structural and sensitive layer between the container contents and the external structural layer (see Figure), the breakdown of the inner liner can be detected at its onset through changes in temperature, strain fields, or a specific damage indicator (e.g. chemical presence). By embedding sensors directly in the manufacturing process of the textile or its layup onto the tank, cost is reduced and quality assurance is increased. With respect to monitoring, damage is detected directly at the local level (instead of through symptoms of the damage such as abnormal volume changes).

T10.4 Standardization

A review and study of the state of the art is critical to this task. Task leader IMMG, in collaboration with DAPP, compiled and studied important references. At the main time Polytect partners are building the state of the art as we push the body of knowledge forward. It is nice to note that Centexbel consortium member Karin Eufinger is chairing the CEN/TC 248 (Textile and textile products) WG 31 (Smart Textile) charged with studying application guidelines and standardization issues for smart textiles.

3.7 WP12: Knowledge Management

Partners Involved: **IKH**, DAPP, CETMA, STFI, KIT,

Work Package Objective: The objectives of WP12 are to

- Provide a platform for the collection, organization, and storage of project knowledge
- To structure and operate a Sensor Measurement Management System that facilitates the display and study of results from different sensors for a case study or field test of interest
- To facilitate the partners in exploiting project knowledge

Work Package Snapshot by Task and Deliverable

Tasks

T12.1 Integration of the technological findings from the WPs
T12.2 Demonstration and Validation
T12.3 Implementation of new materials, IT, machinery, and services

Deliverables

D12.1: Knowledge Management Architecture
D12.2: Software Tool
D12.3: Internet Platform

Work Package Highlights Months 37-48

- ✓ Knowledge management tool placed online
- ✓ Commercial tool version developed
- ✓ Sensor Measurement Management System available

Progress by Task M37-M48

Task 12.1: Integration of the technological findings from WPs

Polytect project, as many times highlighted, is multidisciplinary projects covering two main sector of civil engineering, integrating materials and sensors for the development of multifunctional products. This means that Polytect generated along its four year knowledge and that this knowledge constantly grew. The channels in which this knowledge was spread are different and need to be carefully managed to exploit the best of Polytect results. Within this framework, a knowledge management tool (KMT) was developed to treat and control the significant amount of knowledge and expertise Polytect generated and was finally validated and filled during the 4th year of the project.

This knowledge is partially available on the Polytect webpage (on a secured area). During the 4th year a knowledge link between WP12 and WP13 (Training) has been established.
The KMT for Polytect is available online, in the form presented below by some explicative screenshot, which can be accessed via registered login.

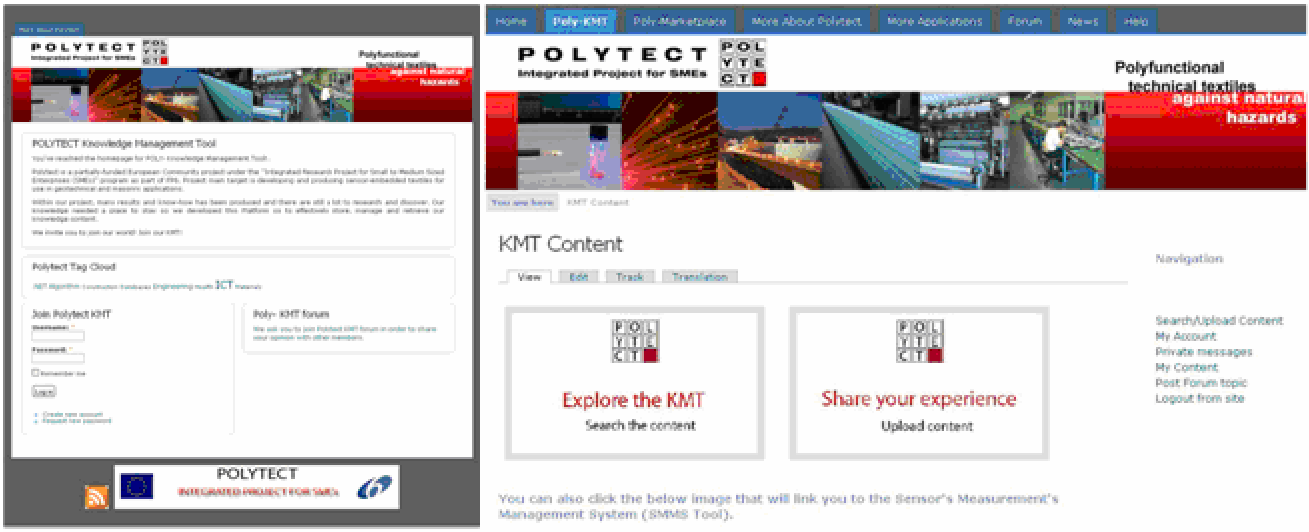


Figure 3.55: Polytect-KMT

Documents can be uploaded, viewed, searched via categories (i.e. for example: health, engineering, ICT), as well as via attributes (i.e. author, language used, country origin). This searching scheme facilitates the search among such multidisciplinary information as the one resulting from Polytect project.

Task 12.2: **Integration of the methodologies from WPs**

The **Sensor Measurement Management System (SMMS)** is available online at the url: http://demo.interten.gr/polytect/m.php?m=measurements&op=recent and is the core of Task 12.2. The purpose of the Sensors' Measurement Management System (SMMS) is to display the data available by the sensors in a user-friendly, graphical form. It is a tool which can provide quick and easy access to a large amount of routinely collected statistical data and help to make use of this information. Data from the shaking table tests conducted at IMMG have been uploaded on the SMMS and became available at the url: http://europe.interten.gr/~polytect/. SMMS is designed to display and compare numerical data that have been provided by the sensors and added as input to the SMMS. The SMMS tool have been developed for internal use of the consortium of the Polytect project. A username and a password have been assigned to each partner and there is not possibility of someone external user to create an account and connect to the system. This has been in order to ensure the system and data security. The navigation of the user starts from the first page of the tool where the menu options and the quick search option are displayed.

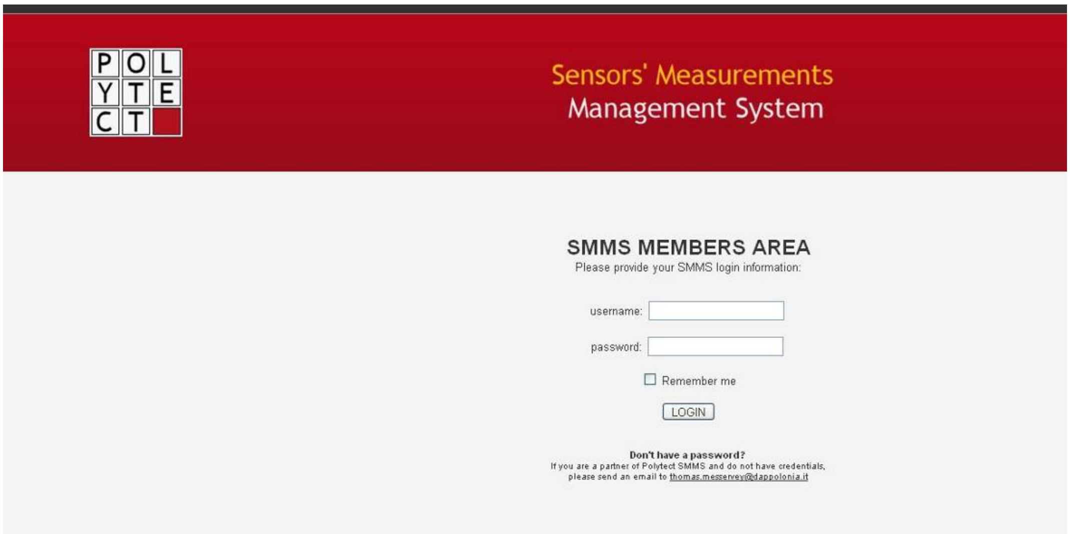


Figure 3.58: SMMS welcome screen

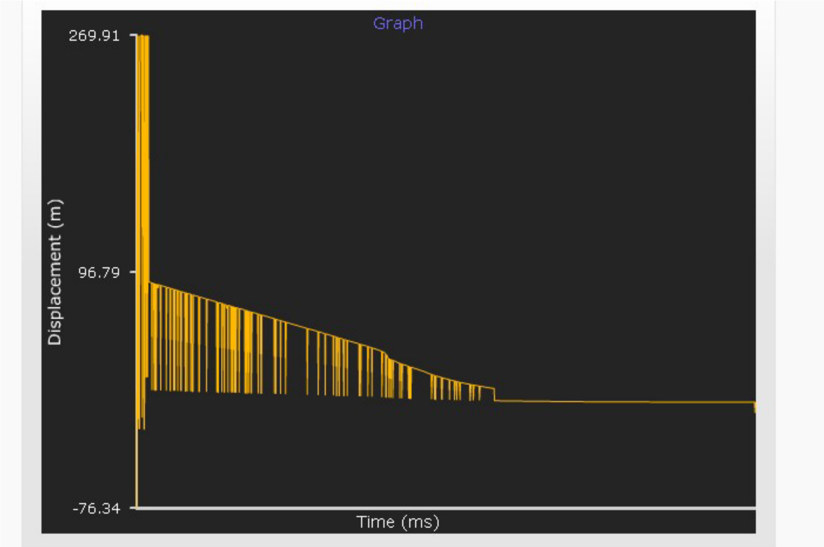
In the first page there is the main menu of the system where all the options are displayed, as well as the quick search option through which the user can search for companies and measurements.

Events

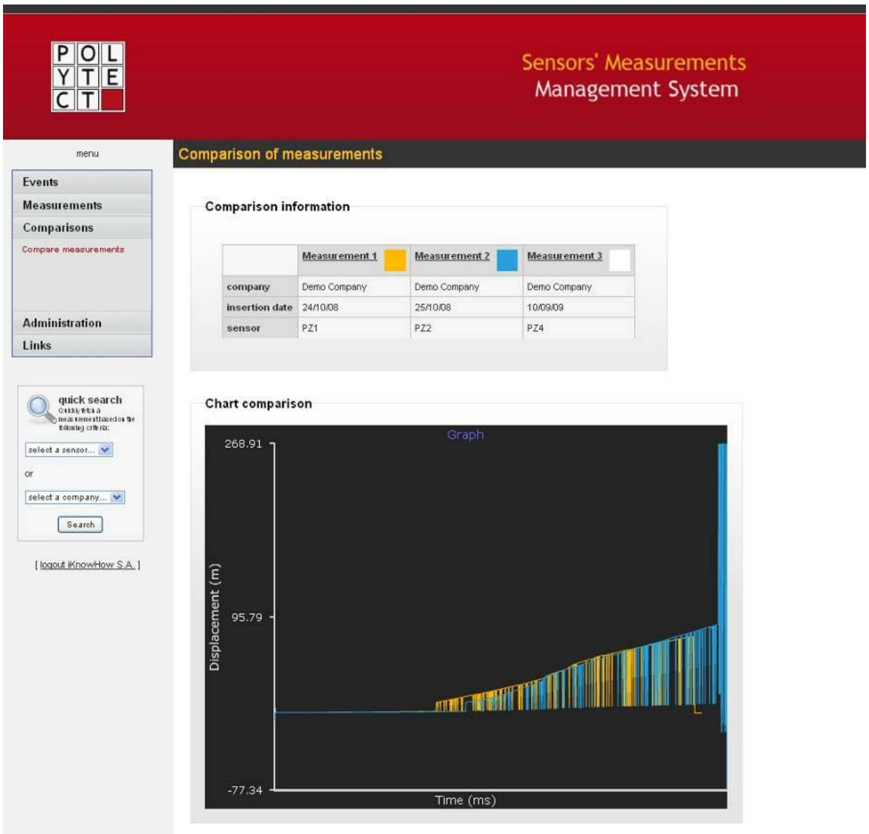
The first option of the menu corresponds to the events where the measurements have been collected.
The drop down menu presents only one option that is "all events"
When "All events" is selected the events that have been organized and from where the measurements have been selected are presented to the user.
When an Event is selected, information for the event ("Event information") and the "sensor map" are presented to the user.
From the sensor map option the user is able to navigate through the measurements through option "view measurements" in the table "Sensor Info".

Measurements

The second option of the main menu of the first page is the "measurements" option, where the subcategories are "My measurements" and "All measurements". The "My measurements" option corresponds to the measurements of the company that have been logged in. "All measurements" option corresponds to all measurements that have been uploaded to the tool.
Graphical functions have been included such as the possibility to visualise the measurements, as shown in the figure below.



Comparisons
From here the user can select up to three measurements and compare them as shown in the following figure.



Task 12.3: Implementation of new materials, IT, machinery and services
DAPP and SMARTEC have drafted and signed an agreement for the launch of SHMLive. This service pairs engineers and monitoring companies to bring SHM monitoring and engineering analysis to the client. DAPP was the first partner worldwide to sign this agreement. Details can be found at http://www.shmlive.com/ and DAPP has submitted its first bid to a client offering this service.

Figure 3.60: Views from SHMLive

3.8 WP13: Training

Work Package Objective:

Training activities of PolyTect create the challenge to transfer a complete picture about very broad multidisciplinary research fields on one side and a highly expertise research competences on the other by design of new conceptual schemes. That includes the design of single but connected training modules for different targeted groups:

1) training to the trainers and 2) training to the user

with support of the use of the software tools developed within WP 12 and WP 14 (Virtual Demonstration Centre). The training courses to be developed will combine courses on production of the new sensors, the integration of the sensors into the textiles and their production, the application of the multifunctional textiles in the construction sector, the optimal use of the POLYTECT technologies for the monitoring, sensing and reinforcement of both earthworks and masonry structures.

Workpackage Highlights Months 36-48:

The development of webinars for training courses which contained:

- ✓ The Project Webinar by D'Appolonia
- ✓ The Technical Textile webinar by STFI
- ✓ The SHM-Webinars by D'Appolonia
- ✓ The customer Webinar by Smartec
- ✓ Training Modules for student courses by CETMA
- ✓ Training Modules for student courses by STFI
- ✓ Summary of all Glossaries

Work Package Snapshot by Task and Deliverable

Tasks

T13.1 Development of training course structure and content
T13.2 Organization of Centres of Excellence

Deliverables

D13.1: Training Material
D13.2: Setting up centres of excellence

Progress during Month 36-48 by task:

Task 13.1: Development of course structure and content for workshops and training courses

✓ Development of training material

According to their fields of competence the partners prepared the structure for training modules as documented in the attached files. The webinar content was chosen to explain the motivation and technical background of the developments made in the PolyTect project.

As discussed before, we focus in WP13 besides the training among the consortium itself on three 3 different targeted "third groups". The targeted groups for future training activities can be differentiated into 3 different levels:

A) students and general public third parties --> interested user on basic level --> webinars to introduce the topic
B) potential customer/industry/Ph.D. students, etc. --> advanced/expert level that means detailed study courses/workshops --> training modules in shape of a lecture

C) local authorities/end user/ customer --> orientation more to motivation (why do I need this product) and global understanding --> TV story about PolyTect (Futuris video)

In particular the training materials cover the following topics:

1. “Case studies of Polytect reinforcing of Masonry Buildings: strips and full-cover solutions (DAPP);
2. “Data processing and data interpretation of fiber optics measurements in masonry buildings field tests” (DAPP)
3. “Physical and mechanical characterization of FRP materials for civil engineering” (CETMA)
4. “Strengthening of masonry structures” (CETMA)
5. “Quality control of FRP Reinforced structures” (CETMA)
6. “Guidelines for the application of FRP materials” (CETMA)
7. “Technical textile in general” (STFI)
8. “Geotextiles” (STFI)
9. “Building textiles” (STFI)
10. “Production processes of technical textiles” (STFI)

✓ Workshop and training activities

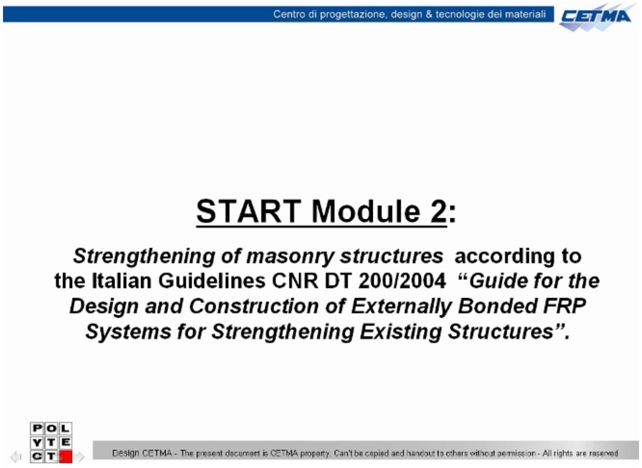
- Advanced Study Course on Optical Sensors - the ASCOS course was held in Madrid (Aug. 26-Sept. 3, 2009) by University Madrid with participation of Polytect partners
- SMARTEC regular info about sensor workshops via e-mail (see http://www.smartec.ch/Training.htm) course on Structural Health Monitoring 23-26 Nov 2009, Manno, Switzerland
- Centexbel – Workshop on Geo & Building Textiles (30.03.2010, Gent, BE)

The final PolyTect Workshop is planned for November 2010 in combination with NanoItalTex in Milano organised by partner TEXCLUBTEC.

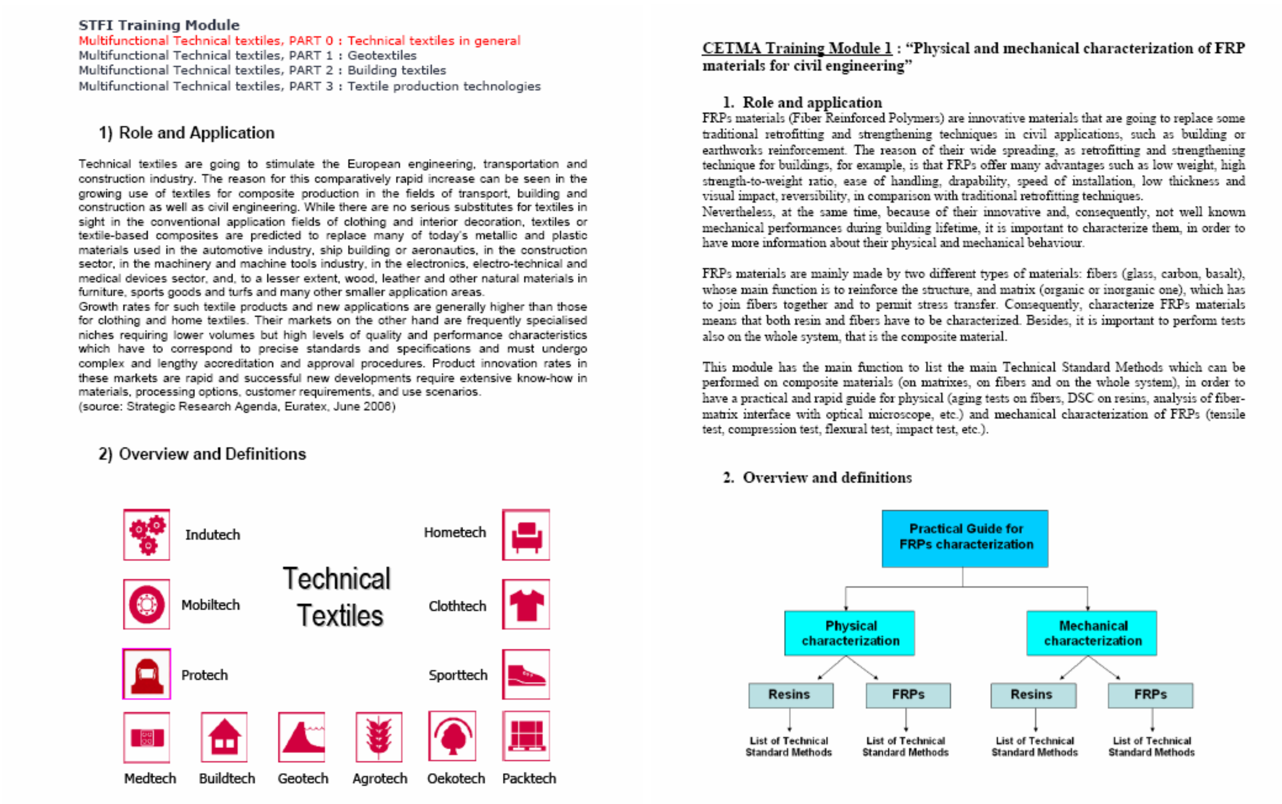
Screenshots of the Polytect webinar are reported below. Polytect partner can access to the whole contents of each webinars at (http://www.polytect.net/index.php?special=changearea&newArea=68), where for un-registered user a short but exhaustive preview is given. Un-registered user can subscribe, to view the whole webinars.

The SHM Webinars (D’Appolonia)

The Technical Textile Webinars (STFI)



The Guidelines and to the market Webinars (CETMA)



STFI Training Module
Multifunctional Technical textiles, PART 0 : Technical textiles in general
Multifunctional Technical textiles, PART 1 : Geotextiles
Multifunctional Technical textiles, PART 2 : Building textiles
Multifunctional Technical textiles, PART 3 : Textile production technologies

1) Role and Application

Technical textiles are going to stimulate the European engineering, transportation and construction industry. The reason for this comparatively rapid increase can be seen in the growing use of textiles for composite production in the fields of transport, building and construction as well as civil engineering. While there are no serious substitutes for textiles in sight in the conventional application fields of clothing and interior decoration, textiles or textile-based composites are predicted to replace many of today's metallic and plastic materials used in the automotive industry, ship building or aeronautics, in the construction sector, in the machinery and machine tools industry, in the electronics, electro-technical and medical devices sector, and, to a lesser extent, wood, leather and other natural materials in furniture, sports goods and turfs and many other smaller application areas.
Growth rates for such textile products and new applications are generally higher than those for clothing and home textiles. Their markets on the other hand are frequently specialised niches requiring lower volumes but high levels of quality and performance characteristics which have to correspond to precise standards and specifications and must undergo complex and lengthy accreditation and approval procedures. Product innovation rates in these markets are rapid and successful new developments require extensive know-how in materials, processing options, customer requirements, and use scenarios.
(source: Strategic Research Agenda, Euratex, June 2006)

2) Overview and Definitions

CETMA Training Module 1 : **"Physical and mechanical characterization of FRP materials for civil engineering"**

1. Role and application
FRPs materials (Fiber Reinforced Polymers) are innovative materials that are going to replace some traditional retrofitting and strengthening techniques in civil applications, such as building or earthworks reinforcement. The reason of their wide spreading, as retrofitting and strengthening technique for buildings, for example, is that FRPs offer many advantages such as low weight, high strength-to-weight ratio, ease of handling, drapability, speed of installation, low thickness and visual impact, reversibility, in comparison with traditional retrofitting techniques.
Nevertheless, at the same time, because of their innovative and, consequently, not well known mechanical performances during building lifetime, it is important to characterize them, in order to have more information about their physical and mechanical behaviour.

FRPs materials are mainly made by two different types of materials: fibers (glass, carbon, basalt), whose main function is to reinforce the structure, and matrix (organic or inorganic one), which has to join fibers together and to permit stress transfer. Consequently, characterize FRPs materials means that both resin and fibers have to be characterized. Besides, it is important to perform tests also on the whole system, that is the composite material.

This module has the main function to list the main Technical Standard Methods which can be performed on composite materials (on matrixes, on fibers and on the whole system), in order to have a practical and rapid guide for physical (aging tests on fibers, DSC on resins, analysis of fiber-matrix interface with optical microscope, etc.) and mechanical characterization of FRPs (tensile test, compression test, flexural test, impact test, etc.).

2. Overview and definitions

Training Modules for student courses (CETMA and STFI)

Task 13.2: organisation of centres of excellence in the research areas of the project
The purpose of this task is to stimulate continued research and excellence in POLYTECT activities both during and after project completion.
DAPP has been involved and is actively part of the Intelligent Manufacturing Systems (IMS) program. DAPP is leading within this framework an initiative "ISMA" for Industrial Smart Material Applications
Actually the platform consists of over 30 members from all 5 participating regions (EU, USA, Switzerland, Korea, and Japan): 35 Individuals, 31 Organizations, 14 Industry, 13 Academic and 4 Research Centres. Notable members outside of the Polytect Consortium include, Stanford University, Micron Optics, UMiami, Instrumentation and Inspection Company of Japan, Los Alamos National Research Laboratory, the Korean Advanced Institute of Science and Technology, the University of Michigan, Princeton, and Virginia Tech.
A third ISMA newsletters have been published at months 38 and the ISMA platform was presented during this last period at the EWSHM2010 in Sorrento, Naples, Italy.

Industrial Smart Material Applications (ISMA)

Manufacture, Build, Monitor, Assess, Predict and Manage

An MTP Key Technology Initiative under the IMS Program

INTELLIGENT MANUFACTURING SYSTEMS

October 2009, Issue #3

In This Issue:

- ISMA Kicks Off!!
- Signing Ceremony
- SMARTEC releases SHMLive
- Company Spotlight: SELCOM
- POLYMAST
- Survey Results

What is ISMA?

ISMA targets industrial applications, test beds, and successful case studies for smart materials with the intent of bringing products, techniques, and services to market that make structural health monitoring, performance prediction, and life-cycle management feasible and cost effective.

What is IMS?

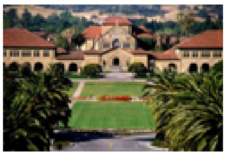
Now in its 14th year, the IMS is an industry-led, global, collaborative research and development program that provides the framework for conducting international manufacturing research by assisting project consortium formation, networking people on a global basis, conducting forums to understand current and future manufacturing requirements, and disseminating information.

What are MTP Initiatives?

The Manufacturing Technology Platform (MTP) is a knowledge sharing platform meant to facilitate the exchange of information and to generate new ideas and research goals. Benefits of participating should include the reduction of individual partner R&D costs, the creation or expansion of market opportunities, and the discovery of global solutions to problems.

Editorial

This will be a quarterly newsletter which puts us in our 3rd quarter of sharing information. That said, ISMA had its official kickoff in September and will become recognized by the IMS program at a signing ceremony in November. Several nice industrial companies have joined the platform recently and one of the underlying projects (POLYTECT) has won a testing opportunity at a major seismic testing facility. We welcome information from you and look forward to your updates!



ISMA KICKS OFF!

ISMA Kicked Off at the 7th International Workshop on Structural Health Monitoring (IWSHM09), 9-11 September 2009, at Stanford University. Two special sessions encompassing 12 presentations were held under the thematic area of Industrial Smart Material Applications. We heard updates on the EU Polytect project, the USA NIST project (self-powered wireless sensors for bridge SHM), research activities at Los Alamos USA, research activities for UAVs in Korea, and case studies employing the SOFO system of SMARTEC in Japan.

We would like to thank Prof. Fu-Kuo Chang for inviting these special sessions and for the organization of a great conference. We would also like to thank especially the non-EU ISMA participating members being their first exposure to the activitiy. These partners included Los Alamos Research Laboratory, MCH Engineering, Physical Acoustics Corporation, MISTRAS, Virginia Polytecnic Institute, the University of Miami, and Princeton University (all USA), IIC Japan, Agency for Defense Development, Korea, and KAIST, Korea. The next ISMA special session will be held 11-15 July 2010 at the 5th International Conference on Bridge Maintenance, Safety, and Management (IABMAS2010) in Philadelphia, PA, USA.

ISMA Signing Ceremony in Geneva

The MOAs will be countersigned at a signing cermony to be held in Geneva, Switzerland, 9-10 November 2009. A formal "induction" will occur during a dinner ceremony. The CEOs of platform industrial companies (as of 4 months ago so recent arrivals are not included) should all have been invited to the event. Travel and accomodation for these individuals are eligible project costs against their respective underlying projects

SMARTEC releases SHMLive

One question that comes up again and again is "How does SHM become viable as a business model for infrastructure managers and decision makers." Typical concerns are life cycle system cost, system maintenance, data management, and who takes care of the engineering analysis?

SMARTEC as part of the RockTest Group has provided their answer to these questions with the release of SHMLive. They are partnering with engineering firms worldwide to provide SHM as a complete, real time, service. In short, SMARTEC will provide the SHM instrumentation plan, conduct installation, provide maintenance of the system over time, and provide real time access to data over the internet. The engineering company provides interpretation of this data and interfaces with the decision makers to assist with the management of that structure over time. The SHMLive service is based on a fixed monthly rate so the users know exactly what their costs will be. D'Appolonia was the first company to sign such an agreement with SMARTEC and enter into the SHMLive program. More details can be found at the SMARTEC webpage at www.shmlive.com or www.smartec.ch.

Figure 3.61: ISMA newsletter

3.9 WP14: Dissemination

Work Package Objective: The objective of the WP14 is the management and transfer of information for POLYTECT. This includes both internal and external web access, workshops and conference participation, an educational platform, and the dissemination of information to potential end users of the exploitable results developed within the project.

Workpackage Highlights Months 37-48

- ✓ Participation at the Techtextil Mumbay (October 2009)
- ✓ Participation at the workshop on Technical organized by Clubtex, Lille (October 2009)
- ✓ Presentation of Polytect project to Japan government delegation (October 2009)
- ✓ Training at the Milan Polytechnic, for a group of students of the Department "INDACO, INdustrial Design, Arte, COmunicazione e Moda (October 2009)
- ✓ Participation at the Nanoitaltex Milano (November, 2009)
- ✓ Participation at the Technical Textiles Meeting Istanbul (December, 2009)
- ✓ Participation at the Euro- Mediterranean conference organized by Taiex, Bruxelles (March 2010)
- ✓ POLYTECT Participation in Composites Europe and JEC Exhibitions 2010, Paris (April 2010)
- ✓ Participation at the EWSHM2010, Naples(June-July, 2010)
- ✓ Participation at the DORNBIRN 49th Man-Made Fibers Congress (September 2010)

Work Package Snapshot by Task and Deliverable

Tasks

T14.1 Development of a Dissemination Plan and Strategy
T14.2 Development of the Virtual Demonstration Centre
T14.3 Conduct of the Dissemination Activities
T14.4 Create the Summary Dissemination Report

Deliverables

D14.1: Dissemination Plan
D14.2: Virtual Demonstration Centre
D14.3: Dissemination Workshops
D14.4: Dissemination Report

Progress by task:

T14.3: Conduct of the dissemination plan and strategy

This task has been being updated with the identification of the main conference, exhibition, and in more in general, occasions for disseminating the project results. Targeted events in the reference period have included:

- ✓ Techtextil Mumbay (October 2009)
- ✓ Training at the Milan Polytechnic, for a group of students of the Department "INDACO, INdustrial Design, Arte, COmunicazione e Moda (October 2009)
- ✓ Nanoitaltex Milano (November, 2009)
- ✓ Technical Textiles Meeting Istanbul (December, 2009)
- ✓ JEC 2010 (April 2010)

- ✓ Training at Milan Polytechnic for the students of the PhD course on Smart and Innovative Textile Materials Strategies and Spin-Off (July 2010)
- ✓ EWSHM2010 (June-July, 2010)
- ✓ DORNBIRN 49th Man-Made Fibers Congress (September 2010)

Figure 3.62: POLYTECT Partner Representatives accepting the JEC Award 2010 for the best innovation in the Building & Construction sectors for the Polytect "Intelligent Seismic Wallpaper" concept

Figure 3.63: Selcom and TexClubTec booths at JEC 2010 with JEC logo, Polytect logo and Poster on display

Figure 3.63: Example of Polytect in Textile Magazines

T14.4: Create the Summary Dissemination Report

Deliverable 14.4 “Plan for Using and Dissemination of the Knowledge” is the reference document for disseminating the Polytect results. It reports the Publishable Executive Summary, updated with the latest results available and the attended dissemination events.

The latest and final version of this report include all the exploitable results produced within the project some of which, as anticipated, are already on the market (see also Task 15.1).

3.10 WP15: Exploitation and IPR Management

Work Package Objective:
The objective of WP15 is to report the exploitation plans of each partner describing the strategies for exploiting newly generated prototypical results and knowledge into marketable products and services.

Work Package Snapshot by Task and Deliverable

Tasks

T15.1 Exploitation plan

Deliverables

D13.1: Exploitation plan

Progress during Month 36-48 by task:

Task 15.1: Exploitation plan
This task is devoted to the Exploitation Plans of each partner, describing the strategies for exploiting newly generated prototypical results and knowledge into marketable products and services. On basis of a market study for the different applications as well as on the basis of the technology watch results (Task 11.2), a common methodology have been developed in order to market and exploit new products and services developed in POLYTECT.
The Exploitation Plan comprises an overview of the publishable results of the project work as well as a list of the innovation-related activities related to exploitation, including past and future activities for commercialization/exploitation per contractor.
D15.1 is the reference deliverable for the exploitation plan. It reports an overview of the final exploitable Polytect products divided into the two fields addressed by Polytect: masonry and earthworks applications. This document captures the results with reference to their characteristic and potential user, their contribution towards innovative applications in the respective field. The strategy to make these products, where needed, available for the market and for a commercial use, is also here addressed. Considerations of further improvements from a technical, as well as, commercial point of view are also reported.
The followings are the Polytect products, named as they have been or will be commercialized, divided into the two fields of application:

- Masonry applications:
  - Sentex8300;
  - Sentex410;
  - Polytect dynamic FBG sensors;
- Earthworks applications:
  - Gedise;
  - Smartec suite products

4 Section 3 – Consortium management

General: The success of the consortium management activities has been directly related to the quality of the consortium, the amount of communication (by all mechanisms), and the number of physical meetings conducted.

Project Level Deliverable Summary Table

The following table shows the state of deliverables in the project for M25-M42. It is noted that previously split deliverables have all been deleted and rejoined as one deliverable. In general, WP3 WP6, and WP7 deliverables were adjusted from the original DOW to reflect the changes in the experimental campaigns for these WPs reflected in the changes made at the 2 year meeting.
A draft PDUK is attached as an Annex 1 to this report, prepared to ensure the USING of the knowledge generated in the project in the long term.

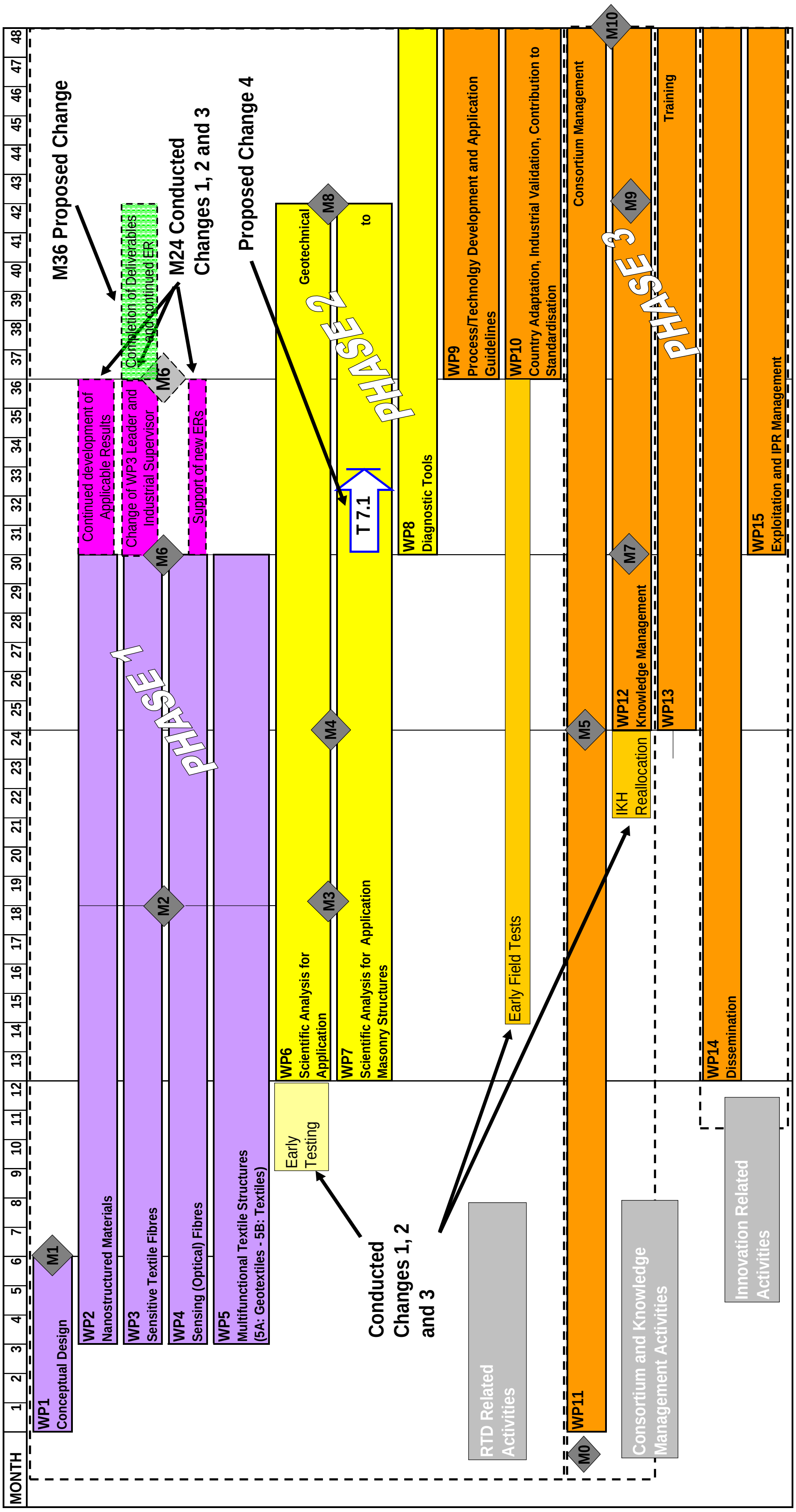
Del. no. (and WP)	Deliverable name	Nature (R: Report, P: Prototype, D: Demonstrator, O: Other)	Date due (M24 DOW)	Actual/ Forecast delivery date	Status/Comment	Lead contractor
D11.2	Periodic Consortium Management Report	R	27	27	Complete	DAPP
D12.1	Knowledge Management Architecture	R	27	39	Complete	DAPP
D14.1	Dissemination Plan	R	27	27	Complete	DAPP
D2.3	Assessment of nanomaterials for new resins/mortars and for fibre/matrix interface (final)	R	30	36	Complete	DAPP
D3.2	Feasibility study report	R	30	35	Complete	Centexbel
D3.3	Small scale laboratory test results	R	30	35	Complete	Centexbel
D4.7	Field trial samples available	P	30	30	Complete	BAM
D5.6	Industrial Trial samples for tests in WP 6 and 7	P	30	30	Complete	STFI
D11.2	Periodic Consortium Management Report	R	30	30	Complete	DAPP
D2.2	Assessment of nanomaterials for smart multifunctional textiles	R	33	33	Complete	CSGI
D7.1	Optimization of fibre and adhesive materials (FINAL – Original split)	R	33	39	Complete	Cetma
D7.2	Calibration and validation of integrated sensors	P	33	33	Complete	Safibra / BAM
D11.4	PUDK Report	R	36	36	Complete	DAPP
D3.4	Assessment on suitable ICPs	R	36	42	Complete	Centexbel
D3.5	Assessment on ultrasonic wave velocity technique	R	36	42	Complete	Centexbel
D3.6	Assessment on suitable nanosized ceramic particles and of related coating processes	R	36	42	Complete	Centexbel
D3.7	Assessment on suitable SSMs	R	36	42	Complete	Centexbel
D11.2	Periodic Consortium Management Report	R	36	36	Complete	DAPP

Del. no. (and WP)	Deliverable name	Nature (R: Report, P: Prototype, D: Demonstrator, O: Other)	Date due (M24 DOW)	Actual/ Forecast delivery date	Status/Comment	Lead contractor
D11.4	PUDK Report	R	36	36	Complete	DAPP
D12.2	Software Tool	D	36	36	Complete	IKH
D12.3	Internet Platform	D	36	36	Complete	IKH
D14.3	Dissemination Workshops	O	36	36	Complete	Textclubtec
D14.4	Dissemination report	R	36	36	Complete	
D7.4	Test results on small-scale retrofitted masonry structures	R	39	39	Complete	CETMA
D6.2	Results of small scale model tests	R	42	42	Complete	Uni-Kassel
D6.3	Results of model tests	R	42	42	Complete	Uni-Kassel
D6.4	Results of numerical investigation and calibration of the model tests	R	42	42	Complete	Uni-Kassel
D6.5	Parameter study	R	42	42	Complete	Uni-Kassel
D6.6	Interpretation of results and adoption of the results to the prototype	R	42	42	Complete	Uni-Kassel
D6.7	Final report	R	42	42	Complete	Uni-Kassel
D7.3	Enhancement of strategies for the retrofitting applications on large masonry specimen	R	42	42	Complete	CETMA
D7.5	Numerical tools for the analysis of retrofitted masonry structures	O	42	42	Complete	CETMA

Project Level Milestone Summary Table

Project milestones in the period are reflected below.

Milestone no.	Milestone name	Workpackage no.	Date due	Actual/Forecast delivery date	Lead contractor
M8	Closure of the experimental campaign and validation of numerical models	WP6 WP7	42	42	Uni-Kassel CETMA DAPP
M9	Training course conducted and knowledge management platform functional	WP12	42	42	IKH DAPP
M10	Field Tests, Diagnostic Tools, and country adaptation	WP12/13/14/15	48	48	DAPP, STFI, TextClubTec, IMMG



Final GANTT (with changes with respect to the initial version)

5 Section 4 – Other

The amount and quality of effort across the consortium is excellent. The question is not what needs to be done and who will do it, but rather how can we keep momentum and leverage the most out of this project opportunity.

The consortium is considering publishing a book as a final report or as additional work after project end. This would be a massive undertaking. It is under investigation. The consortium is also in the process of investigating what systems and relationship need to live beyond the project. This is necessary especially for workshops/seminars where it is inefficient to generate intensive training material for a one-time lesson to a small audience. Instead, it makes sense to produce a training process that can be replicated, reach different audiences, and continue after the project ends. This is supported especially by the industrial partners. In reaching out to an audience as a single entity, one becomes a vendor. In reaching out to an audience as a member of a successful EU project, the result is dramatically different.

6 Conclusions

Polytect had a busy final year and we successfully met the challenge of providing attention to the highest value opportunities for the consortium.

With project closure, some important aspects have been finalized and formalized. Dissemination reports have been turned into product brochures. Project presentations have evolved into training presentations. It is true that we do not have all questions answered and years of research are still needed in this field (especially in the modeling of the textile-mortar-wall and in the development of SHM methods), however, it is the real world implementation of these products that then provide the long-term data for their full evaluation.

The successfully field tests at IMMG, at the EUCENTRE in Pavia, and at the Landfill in Romania are high payoff events. They demanded and received all possible effort from the consortium. Their proper conduct has provide the last opportunity (within the project) to update numerical models, to exercise the Sensor Measurement Management System, and to develop standardization guidelines for project materials.