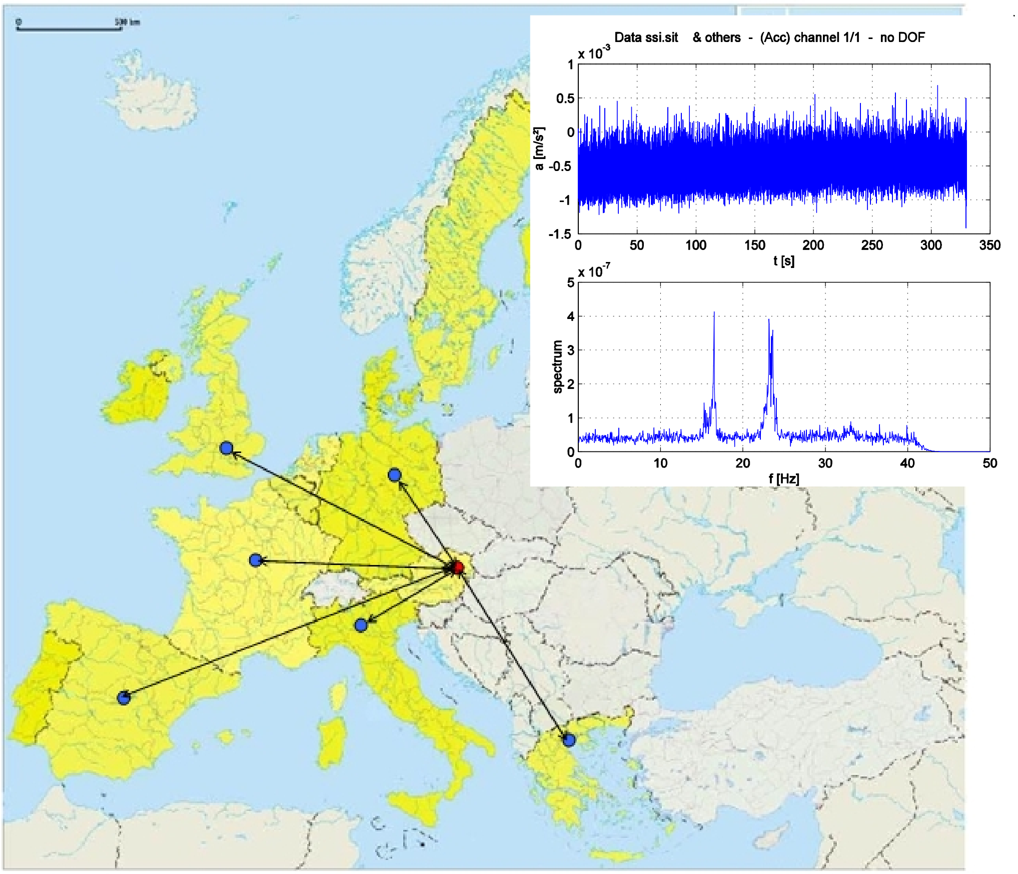
Procedure for Certification



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1 General and Definition

The aim of this report is to develop a certification procedure within the SAMCO project. The work is organised according the proposal, in particular this contribution is related to work package 4 - CERTIFICATION. The objectives of this task in the proposal stage have been:

- To create a certification agency to help overcoming duplication and costly parallel development.
- To enable calibration of methodologies and hardware components.

To fulfil the targets of certification as proposed, the following work should be conducted. This report should serve as draft for implementation of the following tasks:

- Setting up a procedure for certification
- To carry out certification benchmarks
- To contribute to the codes and recommendation of WP 3

Consequently this report is starting point for developing a certification procedure in the post SAMCO time. The main focus should be on certification of the hardware as well as the methodology, because both are an important factor of successful structural assessment and in particular structural health monitoring.

Using vibration analysis to monitor, which means detect and localize damages in civil engineering structures has become yet a key maintenance activity for some structures or structural components. In mechanical engineering, these techniques are representing the current state of the art since several years. There is no machine, car or aircraft developed without excessive analysis of the dynamic structural response. In this field, usually well known and recognised technology is used, due to the fact, that the tasks and the objects under investigations are much more simpler compared to civil engineering structures. Mainly identification of natural frequencies is sometimes sufficient only, to compare a large number of serial products or to maintain the quality of mechanical components which is represented by the modal parameters. Certification of methodology and hardware components is not from importance, because “ready to use” solutions are implemented. The individuals who are performing these tests however, are following a strong trend to training and certification in order to improve their knowledge and quality of work.

The civil engineering situation is different. The structures are usually prototypes, with very inhomogeneous material composition. The sizes are much bigger and testing therefore is much more effort compared to mechanical engineering. From this point of view, structural assessment and in particular health monitoring is a complex procedure. Black-box systems which can be installed on structures are not existing currently, due to the different nature of the given problems and structures. If a monitoring program is required, it must be adapted to the specific structure and the problems to be solved. Thus, quality control and certification during all steps of measurement, data evaluation and data interpretation are from major importance. The effectiveness of monitoring programs in civil engineering strongly depends on three factors which are:

- the capabilities of the individuals who acquire vibration measurements, interpret the data and manage the programs.
- the hardware which is used for the different tasks.
- the implemented software solution, the evaluation method, which is base for determination of the modal parameters. The results are starting point for interpretation of the health condition of the investigated structure.

Due to the fact, that certification does not exist currently for hardware components and evaluation methods, there is considerable room for improvements and ideas. Proposals by the partners what and how to certificate are strongly required, in order to produce a scheme which is useful and recognised later on by the practicing engineers and research institutes which are active in the area of structural dynamics. The specific needs for certification, in particular for the methodology and the hardware components have to be further discussed. Certification of individuals is on the way according to international standards, and should be implemented within SAMCO in strong relation to these codes.

Structural Assessment and monitoring of structures will only lead to useful and reliable results, if the measurement procedure, the measurement technology as well as the evaluation method and software algorithms are developed and used by individuals who have extensive knowledge and experience in the field of structural dynamics. An other aspect is related to the interpretation of results and data by the expert who should have extensive knowledge in the field of structural engineering and structural dynamics.

To ensure the reliability of the measured results, the installation and the quality of the sensors, the data acquisition as well as the maintenance of the measurement equipment is from major importance. All tasks must be under supervision of responsible experts. The condition of the monitoring equipment must be continuously observed. From this two points it is evident, that certification of individuals, hardware components and methodology is strongly interwoven.

From major importance is moreover, if the selected monitoring approach is suitable for the structure under investigation to identify prospective problems and solve different tasks given. This is from significance if major structures (for example large bridges) are investigated, or when the usual inspection interval is not sufficient anymore due to existing damages. In context of certification, the following key-sentence can be formulated:

Qualification and Certification of „Man and Machine“ is required to obtain reasonable, and interpretable results

In the context of certification the following terms should be defined according their specific meaning:

Certificate: Written testimony of qualification issued under the rules of a specific certification system

Certification: procedure used to demonstrate the qualification of an individuals competence in performing condition monitoring measurement and analysis, and leading to the issue of a certificate. Certification does not include operating authorisation.

Certification body: the body that administers procedures for certification of personnel, hardware components and methodology in accordance with this specification.

Recertification: the procedure for revalidation of a certificate through success in an examination

Certification becomes focal point for recognition of the capability and motivation of individuals on one hand, and the technology which comprises the hardware components and the software solution on the other hand.

Health Monitoring by investigating the dynamic structural response is considerably increasing nowadays. University courses on monitoring and condition management are on the increase. Several companies are focussing on maintenance and reliably strategies provided by product suppliers and consultants. Thus, the standard of work quality is varying from excellent to poor and opportunistic depending on the specific contract. In addition several organisations are increasing the amount of labour outsourcing and running contract services. As a result, there is considerably uncertainty within the participating companies and organisations.

Benchmark tests which have been performed within a National (Austrian) Railway Research Project have shown, that the bandwidth of results obtained in shaking table tests was too big. From this point of view, it is from vital importance to certificate persons which should lead to drastic quality improvement of the outcome of structural dynamic tests. This will lead to direct benefits for the certificated company. Clients then know, that the results they have received are derived from a certificated and recognized technology.

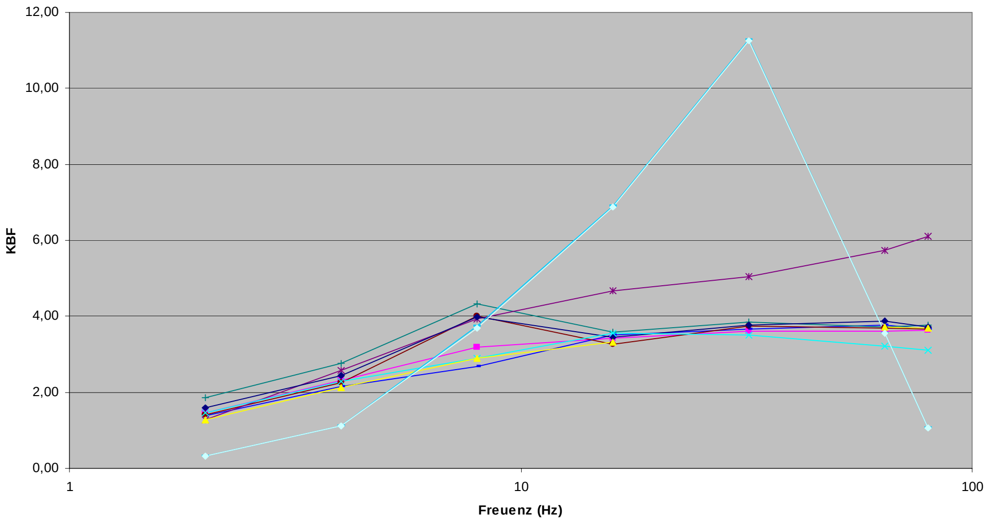


Fig.1: Results of benchmark tests according shock observation

2 Benefits

It is an increasing requirement for non-destructive testing that companies engineers and technicians are able to demonstrate that they have the required level of knowledge and skills. This is particularly due to the fact, that NDT and inspection activities are very operator dependent and those in authority have to place great reliance on the skill, experience, judgement and integrity of the personnel involved.

To get the acceptance for certification by the active companies, it is important to outline the benefits which are created by this quality control mechanism. Certification provides a means for evaluating and documenting the competence of individuals working in the field as well as the suitability of the selected hardware as well as the methodology approach to be used for the specific task. This function is greatly enhanced, when an independent central certification program is administrated according to an accepted reference standard. The aim of the SAMCO Work package 4 is, to develop such reference standard for certification of personnel, hardware components and methodology.

The potential benefits of certification are significant for individuals and employers. Individuals may experience enhanced recognition of technical abilities, improved employment opportunities, and greater sense of pride and responsibilities. The certification program may also motivate individuals to increase their knowledge levels and skills, as well as help in the selection process to identify persons best suited for different applications.

For consulting and technical service companies, supplying certified vibration specialists as well as certified hardware technology combined with sophisticated and certificated software algorithms (in this report defined as “method”) may lead to enhanced **client confidence.**

In the field on non-destructive testing, in particular for evaluating and training of the individuals skill The European Certification Procedure (ECP) is under development. The British Institute of Nod-destructive testing (BINDT) is, together with the French and German NDT Societies (COFREND and DGZfP) are founder member of the ECP which aims to ensure a high degree of harmonization of the application of EN 473 by the National Certification Bodies of the European Federation for Non-Destructive Testing (EFNDT) members, and therefore to provide greater confidence in the resulting certification thus facilitating world-wide acceptance and recognition of the national certificates and competences issued by participants. Due to the fact, that the German BAM is member of SAMCO and is also strongly involved to work package number 4 the development of this certification procedure is in accordance with European guidelines and standards.

3 Preface

Before we start to enter deeper in the filed of structural assessment, monitoring and control (which is the main item of the SAMCO network), it is compulsory to clearly distinguish between the related terms “structural assessment” and “health monitoring”. One has to consider that both terms are going hand in hand, and a separation is based upon the following definitions taken from the literature:

3.1 Structural Assessment

Assessing of existing structures means in particular to evaluate the current condition of civil engineering constructions. The assessment procedure to evaluate concrete, masonry, wood and metal structures can be based upon visual inspections, destructive and non-destructive testing (NDT) methods. Nowadays primary focus in civil engineering is on visual inspection and the application of NDT methods to assess the global condition of a structure. Destructive testing is more important for testing serial products in mechanical engineering and for testing of construction components like concrete and reinforcement steel in civil engineering. The following report is limited to the application of NDT in civil engineering (CE).

Considering this definition of Structural Assessment health monitoring is consequently a component of the structural assessment process, providing the necessary data for the analysis of the health condition of the structure. Generally speaking, the process of health monitoring is a specific measure of structural assessment, which gains considerable importance nowadays due to the need in developing global methods to determine the structural health reliable, fast and cost efficient.

In this context it must be distinguished between local and global approaches either for structural health monitoring as well as structural assessment. Whereas the local approach is related to limited areas on the building under investigation, the global approach always focuses to the whole structure itself. In this context it should be mentioned, that usually a global approach should be employed first in order to identify critical areas where local approaches are then employed consequently.

3.2 Structural Health Monitoring (SHM)

The process of implementing a damage detection strategy for aerospace, civil and mechanical engineering infrastructure is known as Structural Health Monitoring (SHM). The SHM process involves the observation of a system over time using periodically sampled dynamic response measurements from an array of sensors. The extraction of damage-sensitive features from these measurements and the statistical analysis of these features are then used to determine the current “health” of the system. For long term structural health monitoring, the output of this process is periodically updated information regarding the ability of the structure to perform its intended function in the light of ageing and deterioration resulting from operational environments. After extreme events, such as earthquakes or blast loading, structural health monitoring is used for rapid condition screening and aims to provide reliable information regarding the integrity of the structure.

4 Introduction

The stock of civil engineering structures like buildings, bridges, tunnels and many others was increasing all over the world during the last century. Users and owners of such structures, have experienced, that their constructions are reaching a critical age, where rehabilitation and retrofit works become essential. This critical age in average starts after 30 years of service. Owners and maintenance authorities are therefore in a difficult position because public safety is a must and the financial and economic consequence of a structural failure is considerable. Therefore alternative methods and approaches are required in order to manage the huge stock of aging structures in a proper way.

So far, the commonly applied concept of maintenance is based upon a periodic inspection of structures, where usually the simple visual inspection is the first step. Due to the fact, that more objective methods are required to assess structural condition, there is a demand need for new technologies in the field of civil engineering. Several technologies have been developed and applied during the last decade; the commonly used approaches are shown in this current practice report.

Key point in extending the lifetime of structures as well as keeping structural safety to a reasonable limit is to determine the current structural condition by a proper investigation program. Main prerequisite of investigations concerning the structural condition is, that the applied technologies do not have an impact to the structural integrity itself. In addition no negative consequences either to the users of such technologies as well as the environment should occur. Non destructive testing (NDT) of materials and structures plays a significant role for new constructions, development of products and for the implementation in maintenance strategies. Thus, the importance of NDT technologies is still increasing.

The “Current Practice Report on Structural Assessment” mainly represents non destructive testing technologies and has been written to contribute to SAMCO project WP 3. Main aim is to provide fundamental knowledge of these techniques in civil engineering. The currently applied technologies comprise a wide field of different approaches and methods. It was tried to give an overview about the principle, the physics as well as the practical application of the described testing methods. It should be further noticed, that this review could not be a comprehensive survey of all existing technologies, but rather a snapshot of the essential and applied technologies for structural assessment in the civil engineering practice.

Structural assessment and in particular non-destructive-testing is an active and ongoing field of research, which is mainly triggered by the strong requirement from the industry to support subjective visual inspection methods by objective testing and non-destructive evaluation tools. These approaches are mainly based upon physical measurements of structural response or material properties followed by interpretation of the recorded data. Technologies can be classified in two main groups which are looking to the global and local behaviour of structures. Whereas local methods always focus on a part of the structure, global methods employ a response characteristic of the structure to determine the condition and reliability of the whole construction. Local NDT methods shown in the above mentioned report are based on acoustics, eddy currents, hardness testing, magnetic fields, and radiography for example. A successful global approach to assess the structural condition is based upon measurement of the vibration characteristics or the structural deformation during loading. In this context it should be noted, that vibration-based damage detection relies upon the fact, that a local stiffness change caused by a damage, leads to a change in the global dynamic response of the structure.

The main advantage of global methods is, that measurements taken in a few locations of the structure only, are sufficient to assess the condition of the whole construction. Main target of global methods in the first step is, to limit prospective damage areas to local zones in order to apply local NDT methods quantify the extend of damage. A successful maintenance and investigation program therefore should employ both – global and local – methods over lifetime of any structure. Usually there are four levels of damage identification which have to be treated:

- Level 1 – Damage Detection: is the structure damaged or not?
- Level 2 – Damage Localization: where is the damaged area located?
- Level 3 – Damage Quantification: what is the extend of damage?
- Level 4 – Prediction: what is the remaining service life of the structure?

The main groups of non destructive testing approaches can be summarised as follows, a more detailed list concerning techniques which have been used successfully for monitoring civil engineering constructions is prepared in the report already mentioned:

- Mechanical and Optical
- Penetrating Radiation
- Electromagnetic and Electronic
- Acoustic and Ultrasonic
- Chemical Techniques
- Thermal Techniques
- Signal-Image Analysis

5 Certification of personnel - structural vibration specialist (SVS)

5.1 State of negotiation

Basically certification is considered to be a multi-step approach which should comprise all factors which are contributing to the results of health monitoring. Thus, certification of individuals, of hardware components employed and realised methodology, mainly concerning the System Identification implemented, is aimed.

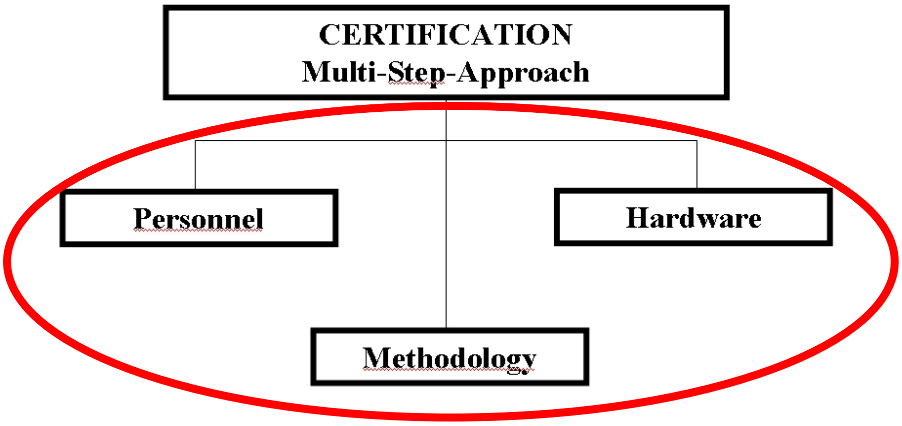


Fig. 2: Scheme of Certification – Hardware, Methodology and Personnel

Whereas certification of individuals is an active field of development where some specific concepts will be realised soon, certification of hardware components and methodology is currently unsatisfactory. In fact there are almost no strategies which are related to quality control and certification of those two blocks “hardware” and “methodology”.

As stated in the project proposal, certification should cover personnel engaged in vibration testing as well as hardware and software components used for testing. Work on the certification program brought up, that certification of individuals carrying out and interpreting tests is from vital importance. Therefore, it was decided to put the focus on <u>certification of personnel as first priority.</u>

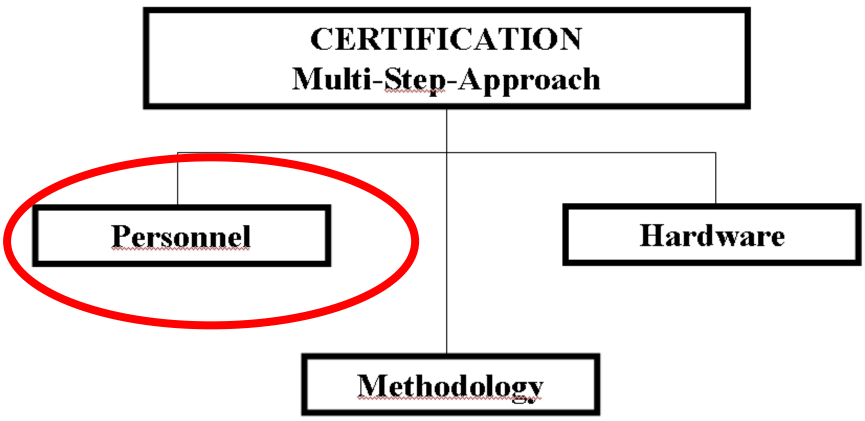


Fig. 3: Scheme of Certification –Personnel

Within the last year of the project the main progress concerning the certification program was performed. In particular this work was related to the screening and catch up to existing certification programs, the existing guidelines and codes as well as certification steps which will be accepted from practice. From this point of view it clearly turned out, that some codes are already existing related to certification of personnel. These codes are valid for non-destructive testing and inspection, and therefore are also valid for vibration technologies employed within this project.

In addition, specific codes and personnel certification programs for dynamic testing and inspection of rotating machines do exist. Based on the clear and distinct vibration response of such machines as well as - in comparison to civil engineering structures – rather simple mechanical systems a clear advance of this technologies is recognizable in terms of diagnosis and application in practice. Thus, several certification programs, guidelines and codes are available.

The certification program developed within SAMCO should consider this experience and already accepted programs. At the beginning of the project, certification of personnel and methodology was aimed in general. In this context, methodology comprises the application of hardware and software tools which are required to reach a specific target. As it was assumed to achieve certification of methodology much earlier than personnel, several concepts were elaborated how to test and certify different components. This comprises for example the correct designation of hardware tools for specific tasks in testing (frequency range, sensitivity, etc.) as well as regular calibration of major equipment. It was suggested that, by presentation of the measurement chain and the submission of technical data sheets, a general suitability of the system for application in dynamic testing in civil engineering could be derived.

But it turned out soon, that the situation concerning certification of software is much more complicated. To enable serious certification of software components, it would be required to show working principles of the programs and tools (codes). This is difficult to obtain from practical point of view, due to confidential reasons. A general applicable certification program considering software therefore seems to be difficult to implement.

A possible approach for certification is the analysis of specific measurement data which are submitted to the company under certification by an independent organisation. This could be done either using artificially generated data or by performing shaking table tests. In the framework of LEO such preliminary tests have already been carried out on a shaking table, resulting in a wide range of results which was a real setback. An additional lack turned out during common testing of a railway bridge. Within this benchmark test which was carried out by suitable equipment, a wide range of different results have been submitted. The detailed analysis of both, the shaking table and the bridge test have shown that the major cause for this wide variety of results was a different and mainly wrong interpretation of the measurements. In general, objective values obtained by the equipment are used for a subjective interpretation by a responsible individual.

These tests clearly have demonstrated that improved education and quality control of personnel is from major importance. Moreover certificated and higher educated personnel will select and further improve measurement techniques with higher sense of responsibility. Certification of personnel therefore is highest priority for the SAMCO network. Therefore a concept was elaborated, which covers the cores of the future certification program:

- Certification of personnel according levels I – III
- Evidence of professional suitability (sufficient education)
- Minimum requirement concerning practical experience in the respective area
- Minimum requirement concerning duration and content of certification courses

- Limited validity of certificate, re-certification required
- Objective, neutral examination using multiple-choice tests
- Low costs for certification to enable wide acceptance in practice
- Designation of national contact points, which are using same material for training courses and supervise exams.

5.2 General Information about the Training Courses

As dynamic monitoring and assessment of structures continue to capture an increased market share, the need also increases for a competent certification of personnel; this being an important integral part of the growing renewable energy industry.

The general idea of the training program is to provide the market with trained experts in the field of dynamic monitoring and assessment of structures who can carry out vibration tests with a following data evaluation and interpretation. Such an accredited training system is seen as the most efficient way to prevent the market from being saturated with poorly trained personnel in structural vibration.

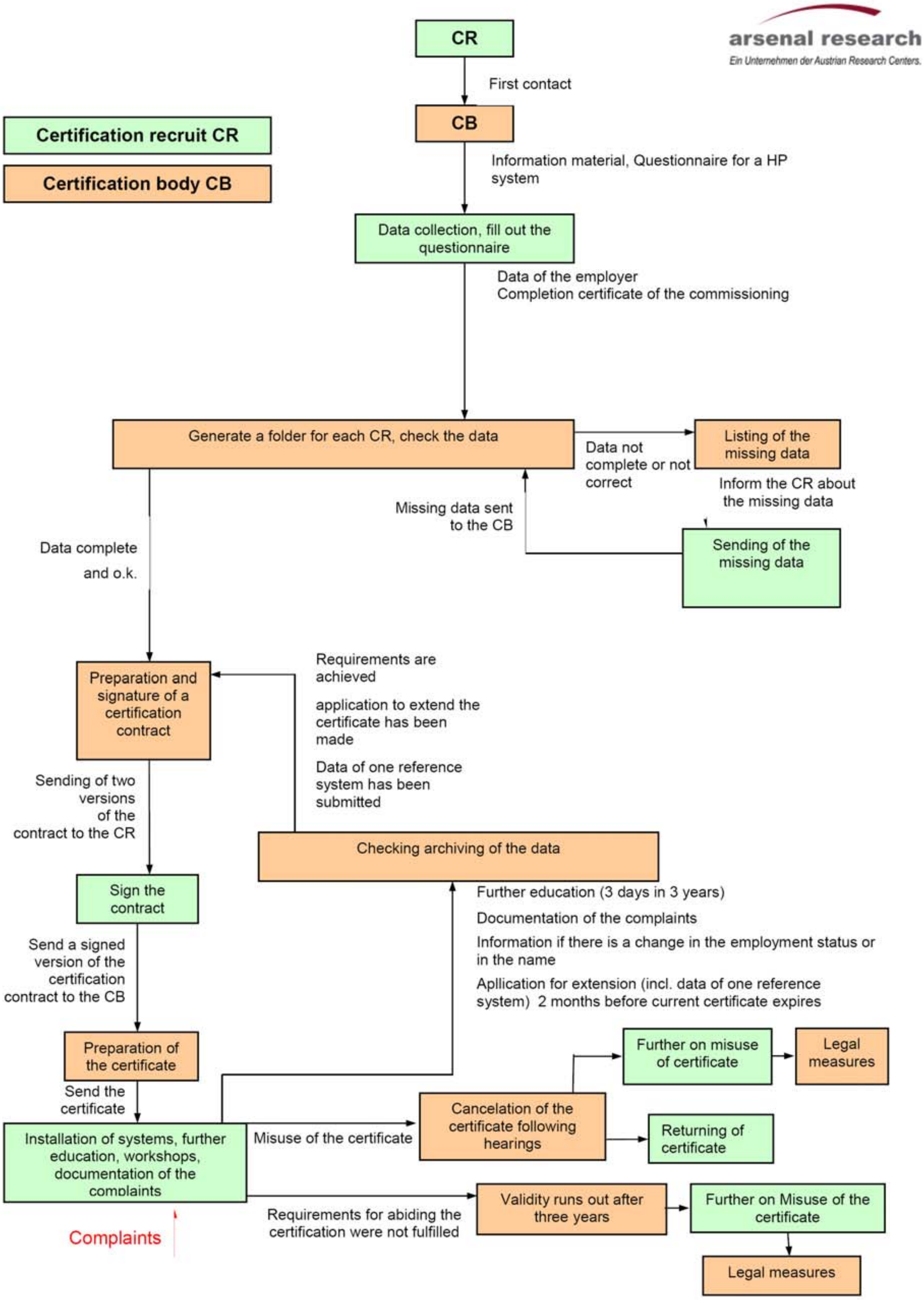
The vision of the certification project is that the training and certification program should be recognised all over Europe and presents a common standard for voluntary further education in the field of dynamic monitoring and assessment of structures in all participating countries. The countries where the training program could be established are shown in Table 1

Table 1: example - countries where the training program could be established

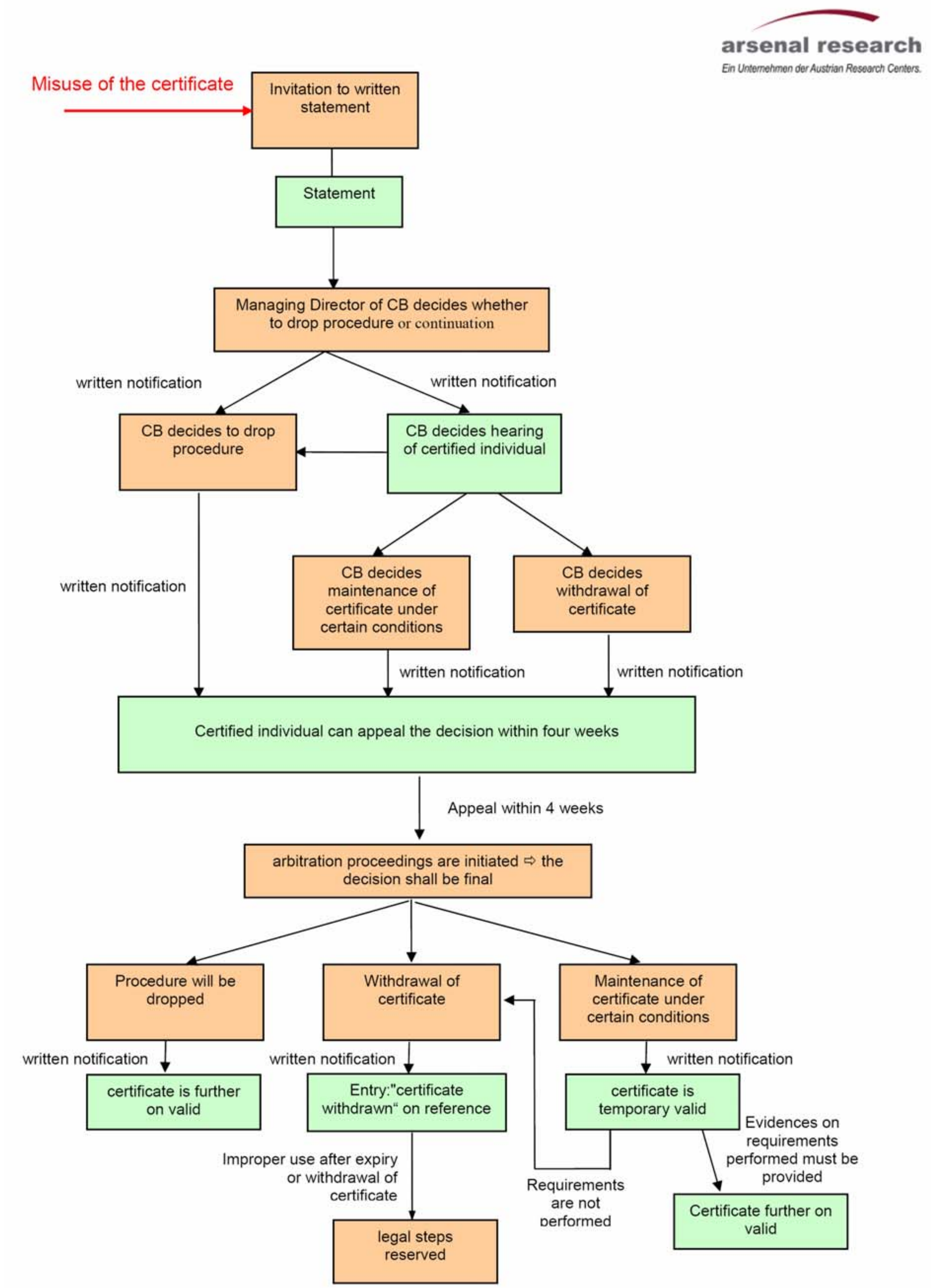
Country	Country Code	Department	Website
Austria	A	arsenal research	www.arsenal.ac.at
Belgium	B	Katholieke University of Leuven	www.kuleuven.ac.be
Belgium	B	Université Libre de Bruxelles	www.ulb.ac.be
Denmark		Danish Maritime Institute	www.danishmaritime.dk
France	F	Laboratoire des Ponts et Chausées	www.lcpc.fr
Germany	D	Bast	www.bast.de
Germany	D	BAM	www.bam.de
Greece	GR	University of Thessaloniki	www.auth.gr
Italy	I	EC-JRC-ISIS	www.ela.jrc.it
Italy	I	University of Pavia	www.unipv.it
Netherlands	NL	Univesity Delft	www.tudelft.nl
Switzerland	CH	EMPA	www.empa.ch

Fig. 4: countries where the training program could be established

5.3 Procedure of certification - process chart as required in EN ISO/IEC 17024*) – example of certification draft of arsenal research



***) NB: EN ISO/IEC 17024: Conformity assessment – General requirements for bodies operating certification of persons –**


arsenal research
Ein Unternehmen der Austrian Research Centers.
Misuse of the certificate
Invitation to written statement
Statement
Managing Director of CB decides whether to drop procedure or continuation
written notification
written notification
CB decides to drop procedure
CB decides hearing of certified individual
written notification
CB decides maintenance of certificate under certain conditions
CB decides withdrawal of certificate
written notification
written notification
Certified individual can appeal the decision within four weeks
Appeal within 4 weeks
arbitration proceedings are initiated ⇨ the decision shall be final
Procedure will be dropped
Withdrawal of certificate
Maintenance of certificate under certain conditions
written notification
written notification
written notification
certificate is further on valid
Entry:"certificate withdrawn“ on reference
certificate is temporary valid
Evidences on requirements performed must be provided
Improper use after expiry or withdrawal of certificate
Requirements are not performed
Certificate further on valid
legal steps reserved

5.4 Definition and Aim of the Training Course

The training course should create a standardised knowledge base. The CERT-training (certification-training) course is free of manufacturer interests/details; it is therefore independent as it does not favour a particular manufacturer or product. Specialised training for a particular product should be undertaken by the manufacturer's product specific training programs.

With the help of this training and certification program a pool of respected and responsible structural vibration specialist (SVS) who are fully competent and who can carry out vibration tests with a following data evaluation and interpretation (incl. FE-modelling and model updating) should be created in all participating countries.

For assuming this responsibility it is important that the structural vibration specialist (SVS) has a good knowledge in dynamics and equally important he/she must be fully aware about his/her rights and liabilities.

In addition to the main aims described above, a secondary aim of the CERT-program is for interested persons from complimentary groups to attend the training program to receive independent information on dynamics technology. By doing this knowledge of vibration tests technology with a following data evaluation and interpretation would become much wider spread and relevant persons would have access to high quality information.

Example: Information to the owners of the structures, the authorities about the avaible methodes

5.5 Target Group

The main target groups are civil engineers which are involved in the field of dynamic measurements.

After completing the training course and passing the examination the structural vibration specialist (SVS) must be able to apply vibration testing with a following data evaluation and interpretation (incl. FE-modelling and model updating).

5.6 Long Term Benefits of the Training

The project will help to train a new generation of motivated structural vibration specialist (SVS). Their growing numbers and their know-how will ensure a continuously growing market. The project will help to develop markets in countries where the presence of structural vibration specialists (SVS) until now is quite modest; this process is expected to be rather effective as a lot of knowledge will be transferable from the already experienced countries.

The training courses will also support the establishment of a SAMCO-network for the exchange of experience and know-how.

Before getting started…

5.7 Administrative Issues of the Training Course

5.7.1 Training Policy

The CERT-SVS training program is fair and accessible to everyone. The training curriculum is orientated to future SAMCO Association, is independent of manufacturer's interests and is regularly updated. The training procedures are practically orientated and are carried out by experienced trainers.

The training curriculum, the quality of the structural vibration specialist (SVS) and the course organisation are all regularly evaluated and improved. The training program is targeted as an independent basic education of a high quality standard. It will serve as a good foundation for continuing training involving manufacturer's product specialisation.

Enclosed we find an excerpt from the Guidelines on the Application of EN 45013

*"**EAC Guidance***

1 The accreditation of a certification body will be expressed in terms of the categories of personnel and the standards or normative documents which they can be certificated as competent to perform.

2 Other limitations may apply, for example restriction to certain offices of the certification body or restriction to certain industrial sectors in which the specific services are to be offered.

3 The assessment and certificate should give confidence to all concerned that the person named in it is competent to undertake specified tasks or has some other specified competence. Reference should be made to documents in which the statement of this competence is given. They could be standards, other normative documents or statements issued by appropriate bodies (SANCO Association) indicating specific competence to which the certificate attests.

4 The format of the certificate is determined by the certification body. The certificate shall identify the person in respect of whom it is issued and the competence of which it is evidence. This should be described by reference to documents as described above and should indicate where these documents can be found together with sufficient references to identify them. The certificate of competence should have an issue date and fixed period of validity or expiry date. It should include the name of the certification body, and of the accreditation body if it is within the scope of accreditation, in which case the fact should be recorded.

5 The basis of assessment should be stated e.g. written examination, practical test, involvement in the field over a period etc or any combination of such.

6 The requirements which the certificated person has met may be so precisely described that two certification bodies acting independently could be expected to reach the same objective conclusion as to whether or not a person complies with them. This may not always be possible. Where it is not the case, the stated requirements cannot be used as a basis for certification without further interpretation. This interpretation should be set out and published by the certification body, preferably in agreement with other bodies operating in the same field and taking account of the views of all interests significantly concerned in the type of personnel certification in question. The knowledge, training and experience required of examiners and assessors may be covered in such interpretations. Accredited certification bodies should take steps to harmonise their standards of assessment, their practices and their interpretive documents and draw them to the attention of other bodies. It may be desirable for the interpretive clauses to be incorporated in the base document. "

5.7.2 Advertising the training program

Each training centre or institute which delivers the courses for certified structural vibration specialist (SVS) is responsible for the advertising and promotion of the courses. Depending on its policy this could be done by direct mailing, web homepage, publishing the course details in the course program of the training centre or institute, press releases, advertisements in relevant journals, etc.

There are only a few rules that need to be obeyed:

- The logo (see Fig. 5) of the certified structural vibration specialist (CSVS) must be inserted into all campaign literature and publications.

Fig. 5: Logo for the certified structural vibration specialist (CSVS)

- The national structural vibration specialist (SVS) education committee must be informed about the training courses. The committee is then responsible for publishing the course dates and information. For example on the national sites of the CERT-SVS-homepage.
- It has to be mentioned that the EU-CERT-SVS training program was established within a European project part financed by the European Commission.
- Any notice and/or publication by the contractors in whatever form and on or by whatever medium, including the internet, must specify that it reflects the authors view and that the commission is not liable for any use that may be made of the information contained therein.

5.7.3 Training Targets

After passing the training program, trainees should be able to apply vibration testing with a following data evaluation and interpretation (incl. FE-modelling and model updating) and be able to coordinate the different teams/persons involved in the measurements process.

This means for example that the structural vibration specialist (SVS) must be able to carry out the following steps, assisted by the training manual of the SAMCO training course:

- Measurement technique:
- Selection of sensor positions
- Sensor selection: applicable frequency range, sensitivity, periodical calibration
- Proper sensor mounting
- Elimination of electrical interferences
- A/D signal conversion, aliasing error
- Excitation technique:
- Ambient excitation
- Forced excitation: - excitation point(s)
  - excitation signal types and their range of applicability
  - excitation devices
- Analysis methods:
- Transfer to frequency domain: FFT, windowing, leakage errors
- Other analysis tools: FRF, PSD, coherence, etc.
- Filtering in time domain: filters and their characteristics
- Natural frequency and damping identification methods
- Mode shape identification methods in frequency and time domain
- Benchmark test
- FE-modelling and model updating

5.7.4 Specifications for Trainers

Due to the fact that the CERT-SVS training courses would cover various topics from different technical and non technical fields it would often be preferable to have different lecturers during the courses. This diversity of trainers would be on the one hand important to communicate the contents in a proper way and would on the other hand liven up the course.

Nevertheless the main purpose of the course is to teach structural vibration specialist (SVS) about vibration testing with a following data evaluation and interpretation (incl. FE-modelling and model updating). Therefore it would be essential that at least one person per training institution would have theoretical and practical experience with vibration testing with a following data evaluation and interpretation.

5.7.5 Training Officer:

The Training Officer is responsible for the contents of the training course, the preparation of the time table and for the recruitment of lecturers. The Training Officer also assists with the organisation, planning and implementation of the training course. The training officer will serve as a contact person for the trainees and for the trainers – before, during and after the training course.

5.7.6 Lecturers:

Lecturers involved in the training courses for certified structural vibration specialists (SVS) must master the subject matter and must be capable of explaining and presenting it. The lecturers can be staff members of the training institute or can be external.

In order to ensure a high training quality each CERT-SVS trainer, independently of the training topic must have a minimum hours training experience. The topics covered by the different lecturers, their knowledge in this field and their training experiences (based on education, further training and professional experience) have to be documented in the form of a CV at the training institute. The lecturers must keep up to date with technical developments in their subject area. It is particularly important that the responsibilities of the different persons are clearly described, e.g. in form of a table as shown in Table 2.

	Training officer	**Lecturer A**	**Lecturer B**	**Lecturer C**
Advertising the course	X			
Organisation, preparation of the time table, accounting, etc	X			
Introduction, Contact person for the trainees	X			
structural vibration I		X	X	
structural vibration II		X		
structural vibration III		X	X	X
data collection		X	X	X
structural behaviour		X		X
vibration analysis		X		
damage identification			X	
Hardware I		X	X	
Hardware II		X		
Etc…				

Table 2: Example of spreading the responsibility between different persons

5.7.7 Train the Trainer Workshop

The Train-the-Trainer Program is designed for individuals who are already experienced experts in their particular field. Prospective trainers must be confident enough of their knowledge and skills to teach them to others.

The CERT-SVS Train-the-Trainer workshops are focused on the content of the trainer handbook and on the other CERT-SVS documents. Participants are taught how to use CERT-training aids, such as manuals, sample curriculum and transparencies used in CERT-workshops. Furthermore, participants are instructed on the course policy, the quality management aspects of the course, the weighting of the topics and the core statements, the course organisation, the course procedures, the required resources, the test procedure and the course evaluation. The Train-the-Trainers procedure is described in the check list for train the trainers. With successful completion of the program, participants will receive CERT-training accreditation and be able to instruct on CERT-SVS training courses. Train-the-Trainer workshops are taught on a national level by experienced members of the national education committee. Each participant will receive a copy of the "Certified structural vibration specialist" manual, trainer manual, presentation aids and handouts.

Accreditation

Upon successful completion of the Train-the-Trainer program and presenting a CV with adequate experience in the special field of teaching, the new teacher will be issued with CERT-accreditation as a trainer of CERT-training courses for structural vibration specialist (SVS) and will receive a trainer's card and a certificate.

5.7.8 Who should attend the training?

The recommended entrance qualifications for the CERT-SVS structural vibration specialist training course are that trainees should already hold some knowledge.

To certify trainees a multi-step approach seems to be useful, which is related to the practical need of vibration specialists to carry out vibration tests with a following data evaluation and interpretation. The levels described in the following section are related to companies and research organisations which are active in the field of structural assessment. For individuals who are working in the structural dynamics environment the following levels are suitable, based upon the responsibilities which are rising during practical testing.

- **Level I:** a trainee certified as structural vibration specialist I is expected to have a basic knowledge of structural vibration, is capable of data collection and periodic monitoring, and be able to perform basic diagnosis and data evaluation. Basically those people would be mainly responsible for conducting the field measurements.
- **Level II:** a trainee which is going to be certified as structural vibration specialist II should have several years (to be discussed – 3 would be useful) practical experience and some theoretic knowledge concerning structural vibration. The main focus must be on damage identification, condition evaluation of the investigated structure, development of monitoring programs and the interpretation of data desired from analysis (incl. FE-modelling and model updating). For a level II specialist knowledge in civil or mechanical engineering is required, depending on the field of activity (civil or mechanical engineering). Those people usually held a University degree and are performing “standardised” data treatment and interpretation.
- **Level III:** these trainees do have detailed practical and theoretical knowledge in the field of structural vibration, do have practical experience of 6 years (to be discussed !) and are capable to perform vibration analysis, data evaluation, damage detection and damage localisation (incl. FE-modelling and model updating). Moreover monitoring hardware knowledge should be available to select the appropriate approach for the specific monitoring task. Those people should hold a PhD. degree in the field of structural dynamics and

should have extensive experience in theoretical and practical application of different methods.

5.7.9 Duration of training

The standardised CERT-SVS -training course could be a 36 hours comprehensive course including 6 hours practical training. The course could be held in the evening, or on a block basis, or spread over several modules or weekends depending on the market requirements of the different countries and the recourses of the training institute. Depending on national requirements the course duration could be enlarged, to add some sort of country specific issues.

The final examination is not included within this course duration

5.7.10 Attendance on the training program

In general, there is no obligation to attend the training course of structural vibration specialist. However, in order to be authorised to sit the final examination it is a prerequisite to take part in the practical training.

5.7.11 Distance learning

All training institutes have the option to organise the courses as a distance learning program. The distance learning system is suitable for all training parts except the practical training and the assessment of the practical achievement. The only obligation is that the subject matter and the targets of the training program must always be covered.

5.7.12 Costs of a Training Course

The costs of the course could vary from institute to institute, depending on the hourly rate of the trainers, the resources, overheads, etc. and must be calculated by the particular institute. It is recommended that the costs of a CERT-SVS training course would be in the region of €150 – €250 per day and should include the manual, hand outs, the examination and refreshments during the training. The cost of attendance on the courses would normally be paid by the trainee or their employer. Government support may be available in some countries.

Information you need…

5.8 Required training resources

5.8.1 Equipment for the training laboratory

Room

A more successful learning environment is one where the theoretical training is carried out in the practical training laboratory where a close link between theoretical and practical training is ensured. Therefore the training lab has to be big enough to accommodate the desks and the practical training equipment.

Measuring equipment

Besides the monitoring program and the capabilities of individuals involved in the process of health monitoring the functionality and quality of hardware components and equipment is a key element of each investigation. Different monitoring technologies and monitoring concepts are selected depending on the structure which is analysed as well as the specific aim of the examination. The main hardware components which are relevant for the data quality obtained by testing and therefore relevant for certification are:

- All types of sensors (displacement, velocity, acceleration, strain, etc.)
- Data cables: important for acquiring data in a good quality. In particular the shielding against external disturbance sources as well as losses due to electrical resistance are key elements of the data cables.
- Data acquisition unit (data logger): the unit should have the ability to sample data with the required sampling rate as well as in a good resolution. Sufficient memory space should be available as well as high A/D conversation.

Basically the technical data sheets and the calibration certificate should be sufficient for certification. Regular re-calibration will be checked during re-certification of the equipment in periodic intervals. This is, to supervise that the time dependent behaviour of several sensor types is regularly checked. For each item which should be certificated, several parameters must be defined which will be checked during the certification procedure.

Demonstration models

To illustrate the application of measuring equipment demonstration models are required. These could include the following parts:

- 2 and 4 meters single span beam in concrete / steel
- 2 and 4 meters single span beam in concrete / steel (partially damaged)

5.8.2 Classroom for the theoretical education

For the theoretical training a standard class room or conference room equipped with tables, lecturer desk, video projector and table or flip chart would be suitable. The best option is if the training laboratory could also fulfil the above mentioned requirements for the theoretical training. Nevertheless in most cases different rooms for practical and theoretical training would be necessary because of space restrictions.

Getting prepared…

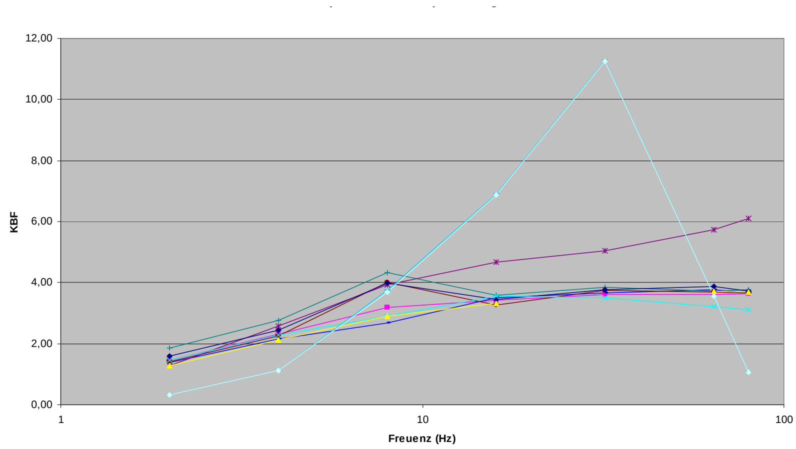
5.9 The Training Program and Performance

5.9.1 Theoretical Training - Methode

Targets of the theoretical training – key competences

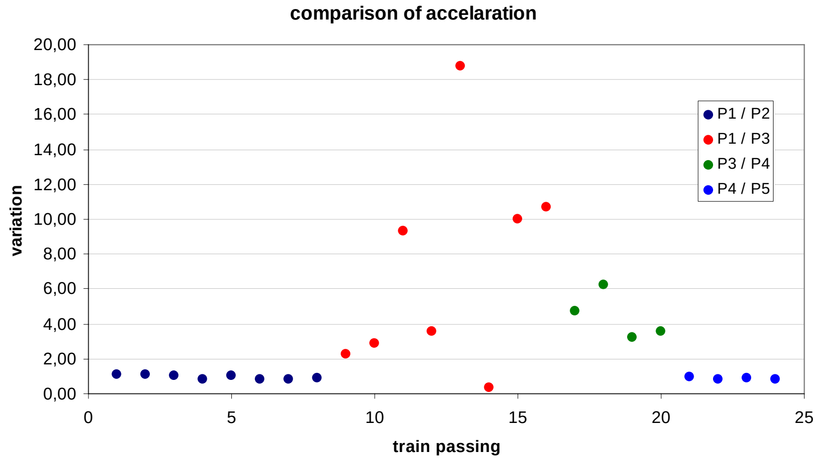
As stated in the project proposal, certification should cover personnel engaged in vibration testing as well as hardware and software components used for testing. Work on the certification program brought up, that certification of individuals carrying out and interpreting tests is from vital importance. Therefore, it was decided to concentrate on certification of personnel as first priority.

A possible approach for certification is the analysis of specific measurement data which are submitted to the company under certification by an independent organisation. This could be done either using artificially generated data or by performing shaking table tests. In the framework of SAMCO such preliminary tests have already been carried out on a shaking table (Graph 1), resulting in a wide range of results which was a real setback.

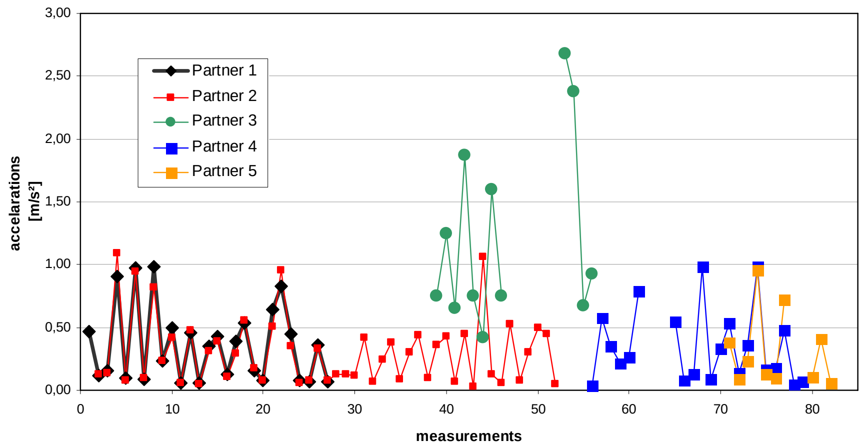


Graph 1: results from a shaking table test

An additional lack turned out during common testing of a railway bridge (Graph 2, Graph 3). Within this benchmark test which was carried out by suitable equipment, a wide range of different results have been submitted. The detailed analysis of both, the shaking table and the bridge test have shown that the major cause for this wide variety of results was a different and mainly wrong interpretation of the measurements. In general, objective values obtained by the equipment are used for a subjective interpretation by a responsible individual.



Graph 2: results of train passing test



Graph 3: results of train passing test

5.9.2 The Training Program

To increase the quality of the measurement, Table 3 provides a list of tasks which have to be known by structural vibration specialists (SVS)

Table 3: Targets of the theoretical training

Task/Skill	Priority
Overview:	
• Vibration Protection • Numerical Analysis of structures under dynamical excitation • Assessment of existing structures • Continuous monitoring of structures	
Structural modelling:	
• Numerical estimation on the base of simple models (SDOF Systems for evaluation of modal parameters); Using of simplified equation and tables from literature, etc. • Structural Modelling (structure, soil): stick models, lumped mass models	

• Structural Modelling (structure, soil):: 2D - models, 3D – models • Model updating	
Numerical methods:	
• Linear dynamic analysis: quasi statically methods, response spectra method, linear time history analysis • Non linear dynamic analysis: non linear time history analysis, Push-over – analysis, quasi – non linear analysis	
Measurement technique:	
• Selection of sensor positions • Sensor selection: applicable frequency range, sensitivity, periodical calibration • Proper sensor mounting • Elimination of electrical interferences • A/D signal conversion, aliasing error	*Must*
Excitation technique:	
• Ambient excitation • Forced excitation: - excitation point(s) - excitation signal types and their range of applicability - excitation devices	*Must*
Analysis methods:	
• Transfer to frequency domain: FFT, windowing, leakage errors • Other analysis tools: FRF, PSD, coherence, etc. • Filtering in time domain: filters and their characteristics • Natural frequency and damping identification methods • Mode shape identification methods in frequency and time domain • “Ringversuche” - benchmark test	*Must*
Approach of modelling / analysis and necessary accompanying documentation	
Pre-Phase: necessary documentation/ basic agreement	
• Performing of a short summary of the task: o Which task field? o Importance factor of structure (see EC8, Tab. 4.3/ EN 1998-1) o Abstract of aims of the analysis o Planned structural model including boundary conditions (e.g. Info if soil will be included) o Planned analysis method o Which codes will be used? o Further relevant internal work instruction • At project beginning: Clarify with client, if publications are allowed and/or project details and public relations (case studies) are permitted. • Definition of dynamic input (e.g. seismic zone; relevant maximum values (acceleration, velocity, displacement); spectra; excitation time histories (natural or artificial generated) • Triage of existing documents o Plan of site; Photo documentation	*Must*

o Expertise of soil o Structural analysis documentations ▪ Which codes has been used; Evaluation of forces, which has been applied to structure during design phase ▪ Evaluation of material parameters, other important parameters, respectively o Concrete forming drawings, reinforced concrete drawings o Experimental results of material parameters (Youngs-Moduli, strength values) • Are the values in the existing documentation plausible, or are tests on random samplings/additional widespread tests necessary? • Performing of a list with according parameters, which has to be additionally evaluated o Emission data, seismic expertise of location, respectively o Geometric parameters (simple measuring, geodetic records, photogrammetry, laser scanning, etc.) o Material parameters (Test specimen; non destructive methods) • If documentation is not complete missing of drawings (e.g. reinforced concrete drawings): own calculations with the codes according to time of construction has to bee done	
Accomplishment/ accompanying documentation/ reports	
<u>Comprehensive documentation</u> for the working on the <u>project</u> has to been done, which should include followings. The <u>reports</u> should only be a compressed, comprehensible reflection of the used documentation, basic assumptions, modelling and analysis method. Focus of the reports should be a detailed and clear presentation of the results. *Aims:* • Documentation should have the possibility of other employees of the dynamic group to work on the project at every stage. • The compressed reflection in the report must be in this form, that an expert can get immediately all the information of the project. The client (if not an expert) has to get an easy to follow, overview (summary chapter for non-experts). This chapter can (if necessary) also include figures for public relations (case studies). • The reports should present the results in easy to follow, graphics etc. • Documentation should include following parts: • Compilation of the finite element mesh: (If FE model is used) o Presentation of models (breakdown) o Accuracy criteria: ▪ Which meshing method has been chosen (why) ▪ Which element types are used (short description in report necessary) ▪ Which frequency resolution is necessary; in which frequency area are realistic results expected o Highlighting of nodes, which suits to experimental measuring point o List of coordinates (a short list in report; eventually as annex) o List of elements (a short list in report; eventually as annex) o List of material parameter • Presentation of experimental evaluated natural frequencies and mode shapes,	*Must*

which are the base for the model updating process • Presentation of natural frequencies and mode shapes, if necessary, performing or parameter studies due to “unsafe” parameters (e.g. min and max boundary values for soil parameters and/or material parameters of structure) • Documentation of the loadings/excitation (statically, dynamically) • Presentation of numerical analysed results (internal forces, deflections); performing or parameter studies due to “unsafe” parameters (e.g. min and max boundary values for soil parameters and/or material parameters of structure, eventually parameter studies of loading/excitation values, e.g. using of different spectra) *Annotation:* Feasibility of parameter studies should be clarified with the head of business unit for every project. • Documentation of additional design calculations (e.g. RC-Column for moment and normal force) • Plausibility check: for 2D and 3D model, important results (first natural frequency, important internal forces and deflection should be verified with simplified methods). • For 2D and 3D models of buildings, e.g. storey masses have to be calculated and documented. By using of principle of virtual forces (Force “1” at floor level) the stiffness matrices should be calculated, which can be used for a “lumped mass” model. For all other structures, the procedure should be the same. The matrices should be included in a template together with natural frequencies and mode shapes of the simplified model. This model is very useful for plausibility checks. • Documentation of eventual model – updating processes.	

5.9.3 Training methods

The theoretical training course (spoken in English) includes the following teaching procedures:

- Lectures supported by power point presentations
- Explanations that link closely to the practical equipment (demonstrations in the laboratory)
- Links to the practical training
- Examples
- Calculations
- Group work (discussions, calculations)
- Regular reviewing (tutorials)
- FE modelling and model updating

By structuring the course in this way, participants are encouraged to take an active role in the training course. The learning process is constantly being checked by regular similar exercises and questions so that if necessary, the speed at which the lectures are being presented can be adapted.

5.9.4 Practical training - targets

During the practical training course, the participants should acquire the following skills:

- Selection of sensor positions
- Sensor selection: applicable frequency range, sensitivity, periodical calibration

- Proper sensor mounting
- Elimination of electrical interferences
- A/D signal conversion, aliasing error
- Ambient excitation
- Forced excitation:
- - excitation point(s)
- - excitation signal types and their range of applicability
- - excitation devices
- Transfer to frequency domain: FFT, windowing, leakage errors
- Other analysis tools: FRF, PSD, coherence, etc.
- Filtering in time domain: filters and their characteristics
- Natural frequency and damping identification methods
- Mode shape identification methods in frequency and time domain

5.9.5 Round-robin tests and benchmark tests

Benchmark tests or round-robin tests are a very important tool for the practical training program. These tests should be a precondition for every training course, because the attendees can learn a lot about measurement uncertainties and typical measuring errors.

A benchmark test or a round-robin test has the following objectives

- confirmation of the ability of the attendees to measure the requested data
- confirmation of the reproducibility and repeatability of the test
- confirmation of the appropriate measurement equipment
- comparison of data, systems and personnel from different measurements
- comparison of measurement uncertainties und measuring errors

For the test layout it is important that all attendees are able to measure the same input data. This can be established by identical demonstration models. If the test is conducted in the field (for example: a bridge excited by the passing by of trains), it can become quite difficult to get comparable results. For such tests the environmental influences have to be taken into account.

The test procedures have to be as clear and similar as possible. The data that should be measured must be stated clearly before the beginning, so that all participants have a good knowledge of the expected results. Former tests have shown that a different understanding of the objectives can lead to a wide variety of results. The results must be evaluated according to the agreed evaluation and assessment criterions. The outcome should be presented to all participants. The detailed results should be accessible to all to ensure a further development and enhancement.

Certification could be based upon the following procedures, which should cover problems which are evident in practical field testing and data evaluation:

- Evaluation of artificial generated test data, which will lead to specific and well known natural frequencies, mode shapes and damping coefficients.
- Evaluation of field measurement data, in order to assess the efficiency of the system identification technology in case of field test data which are acquired under low response, ambient vibration. This should outline the sensitivity of the methodology. Mainly frequencies and belonging mode shape information could be derived.

- For extensive testing it is thinkable to realise shaking table tests in different partner institutes within the SAMCO network. Therefore a specific test program should be prepared, which is providing signals with specific time-history.

5.10 Examination procedures

5.10.1 Requirements

Participation in the certified structural vibration specialist training course, participation in the practical training and the written application for the examination are prerequisites for the final examination.

5.10.2 Targets of the examination

The final examination takes place at the end of the training course and is proof that an individual has mastered the important training issues covered by the training program.

5.10.3 Preparations for examination

The examination could be split into two parts, the theoretical examination and the assessment of practical competence.

The assessment of practical competence can be organised directly after the completion of the practical training – to minimise the travelling time of the examinee.

The theoretical examination should be arranged between two and three weeks after the training course and could be done via computer or as a typical written task. The examination could be held in the training institute or in another institution. It has to be ensured that the institute where the examination is organised verifies the personal details of the examinee preventing another individual taking the examination on behalf of the examinee. Also if the examination is arranged at an institute close to the examinee's place of work or residence then their travelling time could be reduced.

The date of the examination has to be published at the commencement of the training course.

After the training…

5.11 Post processing of training

5.11.1 Preparation of training feedback

It is a requirement that each course is evaluated; as a minimum this can be by the CERT-SVS questionnaires. Additionally it is up to each institute whether to evaluate the course by its own standard evaluation procedure.

5.11.2 Feedback from the trainees:

The evaluation will take place at the end of the training course – after the practical training. The trainer will distribute the CERT-SVS -trainee-questionnaire to all trainees and should strive to get all the questionnaires returned. The feedback from the trainees is anonymous. A template for the CERT-SVS -trainee-questionnaire can be found in the appendices

5.11.3 Feedback from the trainers:

In addition to the above, feedback from the trainers is very useful for the quality control of the training program, especially during the first pilot courses. Every new trainer is required to complete the CERT-SVS -trainers-questionnaire at the end of the training course. A template for the CERT-SVS -trainee-questionnaire could be found in the appendices

5.11.4 Evaluation of the training feedback

The training feedback needs to be evaluated by each institute. At least once per year the institute needs to present a short feedback summary to the national education committee. This valuable feedback from the participating countries will be presented during the meeting of the international education committee and will be essential for the continuously updating of the training program.

5.12 Certification procedures

The certification system is based on a continuously working quality control cycle based on the following main steps. The initial step is the first certification which is bound to the certification requirements.

This initial certificate could be valid for three years; within these three years the certified person must fulfil regular certification criteria. After the three years validity the criteria will be checked and if the requirements for extension are fulfilled then it will be extended for the next three years. If the requirements are not fulfilled the validity of the certification will expire and the person can not use the title certified structural vibration specialist (CSVS). Furthermore his contact information will be removed from the reference list of certified installers.

The general procedures of the certification system are shown in Fig. 6.

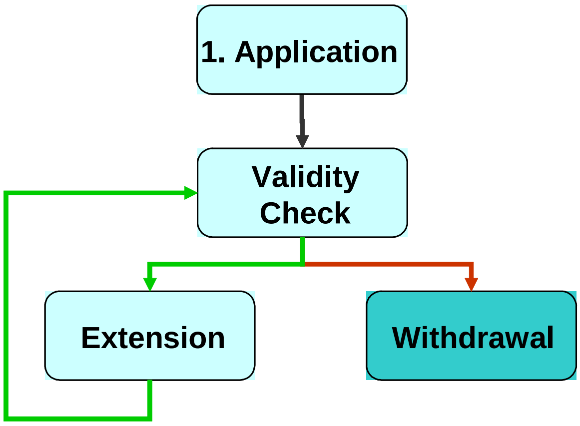


Fig. 6: general procedures of the certification system

5.12.1 First application of the certificate

For the first application of the certificate the following minimum requirements must be fulfilled:

- Signed certification application form
- Participation certificate confirming completion of the CERT-SVS training or of an equally valid training course
- Successfully passing CERT-SVS final examination
- The employer of the applicant must be operating as an engineer by a civil engineer
- Written confirmation from the employer that the applicant has at least 2 years experience

5.12.2 Requirements for Extension

In order to maintain skills, the following requirements for certification must be met in the next three years following certification.

- An application to extend certification must be signed
- The certified person must be active in the dynamic field sector

- Any change in employment or change of name must be sent in writing to the certification body
- Every three years, the certified person must participate at least in one half day of further education relevant to the field of dynamic technology.

Every six years after the initial certification the knowledge of the certified person will be checked to ensure that it is relevant and up to date. Therefore in addition to the above requirements, at six year intervals the structural vibration specialist has to pass an examination. This examination could be a written or an oral examination that is evaluated by the national certification body. The topics of the examination is to be focused on new technical developments in structural dynamics technology and relevant information in respect of standardisation and national requirements.

The sequence of validity checks is shown in Fig. 7.

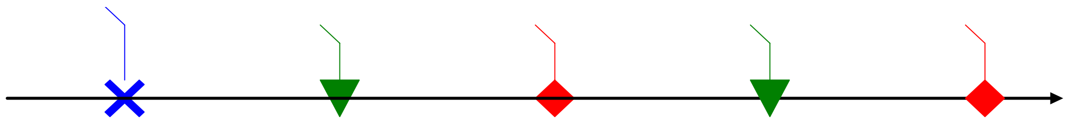


Fig. 7: Sequence of the required validity checks for certified structural vibration specialist

5.12.3 Validity of the certificate and extension of certification:

The certified structural vibration specialist certificate is valid for 3 years from the date of issue.

A written application to extend the certificate should reach the certification body at the latest 2 months before the current certificate expires. Once these records have been examined, a new certification contract is signed before a new certificate is issued.

For as long as the certificate is valid, the certified individual is entitled to use the certificate for publicity purposes. Furthermore, all certified individuals are included in the reference list of certified structural vibration specialist, which can be found on the website of the national certification body.

5.13 Usefully codes

Concerning certification of personnel there are some existing codes which are listed here:

EN ISO/IEC 17024	Conformity assessment – General requirements for bodies operating certification of persons
ISO 9712	Non-destructive Testing – Qualification and Certification of Personnel
TC 108/SC 5	Condition monitoring and diagnostics of machines
ISO/FDIS 13372	Condition monitoring and diagnostics of machines – vocabulary
ISO/AWI 13374-2	Condition monitoring and diagnostics of machines – data processing, communication and presentation – part 2: data processing
ISO/DIS 13381-1	Condition monitoring and diagnostics of machines – part I: general guidelines
ISO/DIS 14830-1	condition monitoring and diagnostics of machines – tribology based monitoring and diagnostics – part I. General guidelines
ISO/DIS 18436-1.2	Condition monitoring and diagnostics of machines – requirements for training and certification of personnel – part I: requirements for certification bodies and the certification process.
ISO 18436-2	condition monitoring and diagnostics of machines – requirements for training and certification of personnel – part II: vibration condition monitoring and diagnostics.
ISO/CD TR 19035	survey of techniques used for the purposes of condition monitoring and diagnostics of machines.
EN 45013	general criteria for certification bodies operating certification of personnel
EN 473	general principles for qualification and certification of NDT personnel
ISO 11484	Steel tubes for pressure purposes – qualification and certification of non-destructive testing personnel
EN 4179	Aerospace series – qualification and approval of personnel for non-destructive testing
ANSI-CP-189	ANSI/ASNT standard for qualification and certification of non-destructive testing personnel
AIA-NAS-410	Aerospace industries Association national aerospace standard for qualification and certification of non-destructive testing personnel
SNT-TC-1A	ASNT recommended practice for the qualification and certification of non-destructive testing personnel (periodically reviewed and republished by the American Society for NDT).

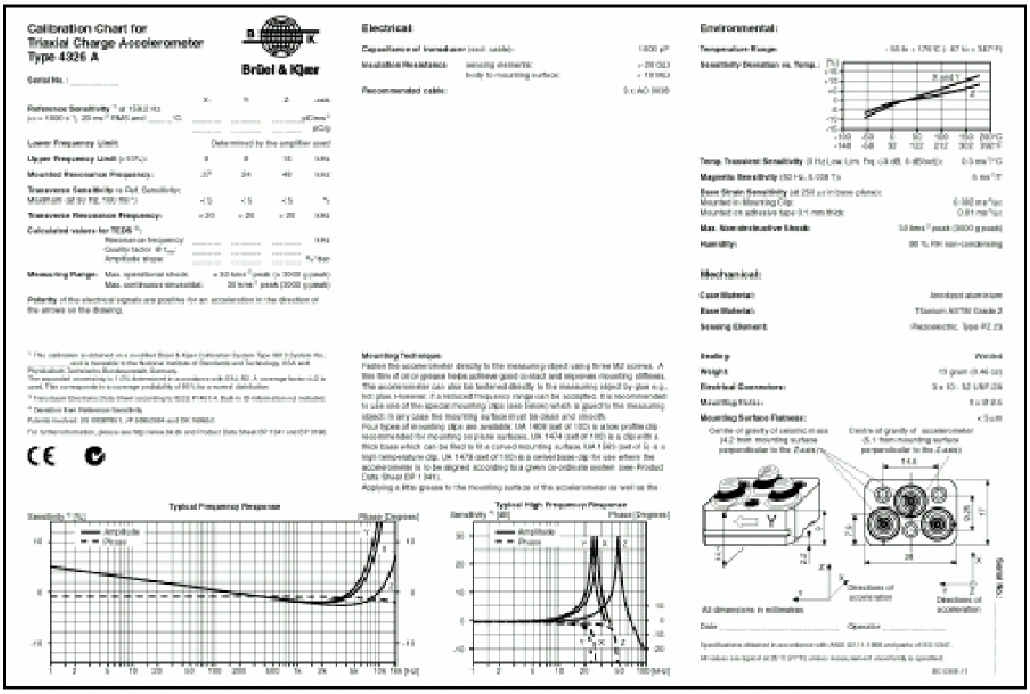
6 About hardware and software

6.1 Hardware

Besides the monitoring program and the capabilities of individuals involved in the process of health monitoring the functionality and quality of hardware components and equipment is key element of each investigation. Depending on the structure which is analysed as well as the specific aim of the examination different monitoring technologies and monitoring concepts are selected. The main hardware components which are relevant for the data quality obtained by testing and therefore relevant for certification are:

- All types of sensors (displacement, velocity, acceleration, strain, etc.)
- Data cables: important for acquiring data in a good quality. In particular the shielding against external disturbance sources as well as losses due to electrical resistance are key elements of the data cables.
- Data acquisition unit (data logger): the unit should have the ability to sample data with the required sampling rate as well as in a good resolution. Sufficient memory space should be available as well as high A/D conversation.

Basically the technical data sheets and the calibration certificate should be sufficient for certification. Regular re-calibration will be checked during re-certification of the equipment in periodic intervals. This is, to supervise if the time dependent behaviour of several sensor types is regularly checked. For each item which should be certificated, several parameters must be defined which will be checked during the certification procedure. An example which parameter is from relevance for acceleration sensors is shown in the following section.


Calibration Chart for
Triaxial Charge Accelerometer
Type 4326 A

Brüel & Kjær

Electrical:

Environmental:

Mechanical:

Typical Frequency Response

Typical High Frequency Response

Fig. 8: Data sheet of an acceleration sensor

- Full Scale Range
- Natural Frequency
- Normal Damping
- Full Scale Output
- Zero Offset
- Sensitivity
- Linearity
- Noise
- Dynamic Range
- Calibration
- Turn On Time
- Temperature Effects (Zero Drift)

Certification is performed by going through the demanded parameters and comparing them to the regulations of certification. Improvements concerning the detailed technical data which are basis for certification will be done until the next SAMCO meeting and based upon the comments received from the other partner.

Moreover it should be discussed, if detailed hardware testing and certification on shaking tables are reasonable. These tests are the own possibility to assess the real response of sensors besides the technical information given on the data sheets. The practicability of the certification procedure must be considered if this task is implemented.

6.2 Method/Software

From a national (Austrian) research project it was derived, that the results from a shaking table test, providing vibration with specific frequencies and peak accelerations are varying in the range of 100%. Whereas it was commonly achieved to identify natural frequencies under this test circumstances, it was much harder to derive reliable amplitude information. Therefore, a certification of the methodology implemented for System Identification is from considerable interest to improve the quality of data evaluation. Certification could be based upon the following procedures, which should cover problems which are evident in practical field testing and data evaluation:

- Evaluation of artificial generated test data, which will lead to specific and well known natural frequencies, mode shapes and damping coefficients.
- Evaluation of field measurement data, in order to assess the efficiency of the system identification technology in case of field test data which are acquired under low response, ambient vibration. This should outline the sensitivity of the methodology. Mainly frequencies and belonging mode shape information could be derived.
- For extensive testing it is thinkable to realise shaking table tests in different partner institutes within the SAMCO network. Therefore a specific test program should be prepared, which is providing signals with specific time-history.

A possible approach is, that the company under certification is receiving data sets including some general description (sampling frequency, sensitivity of the sensors etc.) in ASCII format by e-mail for the generated and ambient data. In addition an evaluation form is coming along with the data where characteristic results, like identified modal parameters as well as some selected figures (frequency spectrum for specific range, etc.) will be included finally. This document represents the ability of the system identification technology and will be sent back to the certification institute for assessment after data treatment.

Basically the modal parameter natural frequency, mode shape and damping coefficients which are derived by the different System Identification technologies are assessed. State of the art SI comprises methods in frequency and time domain according table 1.

	Type of Method	**Characteristics**
Methods in Frequency Domain	Peak-Picking	Classical SDOF method
	Frequency Domain Decomposition (FDD)	MDOF method; application of SVD to reduce noise
Methods in Time Domain	Random Decrement (RD) Technique	Operates on time domain series, leading to a freedecay curve analysis
	Rekursive Technique (ARMA)	Time series modelling using recursive algorithms
	Maximum Likelihood Methods	Stochastic methods based on the minimization of al covariance matrix
	Stochastic Subspace Methods	Stochastic methods based on the projection of a state vector on a vector of past realizations

Table 4: Recently applied System Identification techniques

The test benchmarks as well as the belonging evaluation forms will be developed for the different test cases within the SAMCO network as soon as possible.

6.2.1 Artificial Test Data

Whereas it is rather easy to obtain natural frequencies and mode shapes from ambient (field measurement) test data, it is very difficult to derive reliable damping coefficients. The bandwidth of damping coefficients is considerably almost within one methodology, depending on the data quality and the signal-to-noise ratio. In this context it should be mentioned, that comparative studies have shown that the Stochastic Subspace Identification is the most powerful and reliable identification method for damping coefficients. All other “low technology” approaches do only lead to estimate values of damping coefficients. Certification based upon treatment of real (ambient) test data seems therefore to be a critical approach.

To solve this problem the best procedure is to create artificial test data, with well known natural frequencies, mode shapes and in particular damping coefficients. This could be realised by superposition of several harmonic signals either in ANSYS or in MATLAB writing into an ASCII file. Several test signals have to be created, in order to prevent that all results should be well known in advance.

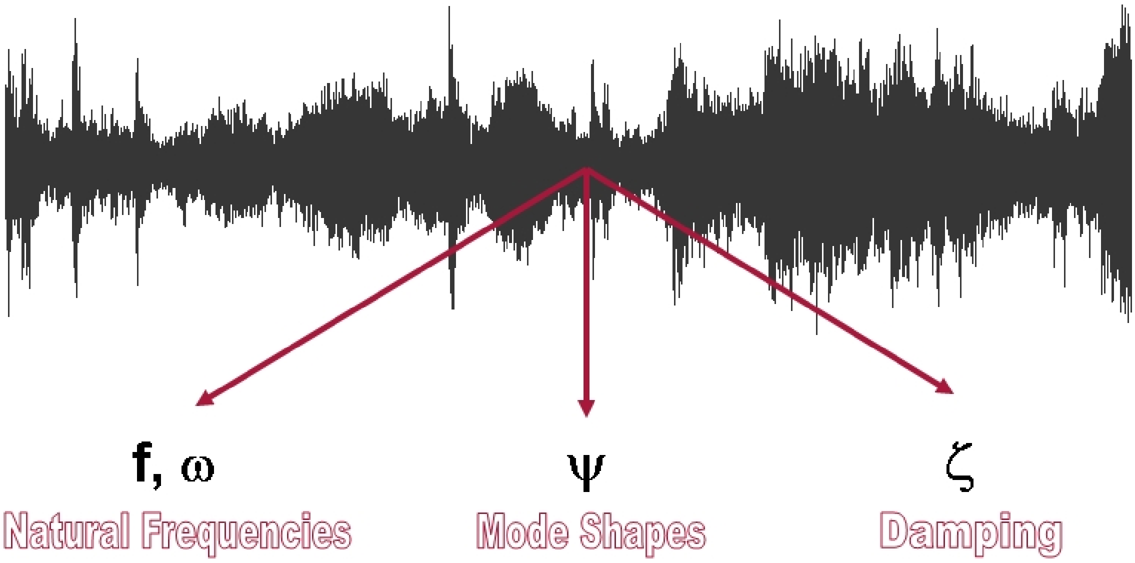


Fig. 9: Modal parameters to identify

Criteria for assessment are the identification of accurate natural frequencies, mode shapes and damping coefficients by evaluation of the generated test data. The allowed bandwidth of results derived should be very small because all parameter are defined exactly during the data generation. Of course the bandwidth must b increased for assessment of the results obtained by the evaluation of ambient test data.

6.2.2 Evaluation of Ambient Data

The capacity of System Identification technologies concerning diversion of modal parameter is represented best in the treatment and evaluation of selected ambient test data. In particular the ability to obtain reliable results for low signal-to-noise ratios should be proven. Several SI technologies applied by the different companies and research institutes should show their efficiency in identification of closely spaced modes for example and the separation of real mode shapes from operational deflection modes. Damping estimates could be calculated as well to assess the spread of results. Criteria for assessment of ambient data is the ability to identify natural frequencies and mode shapes in a specific frequency band.

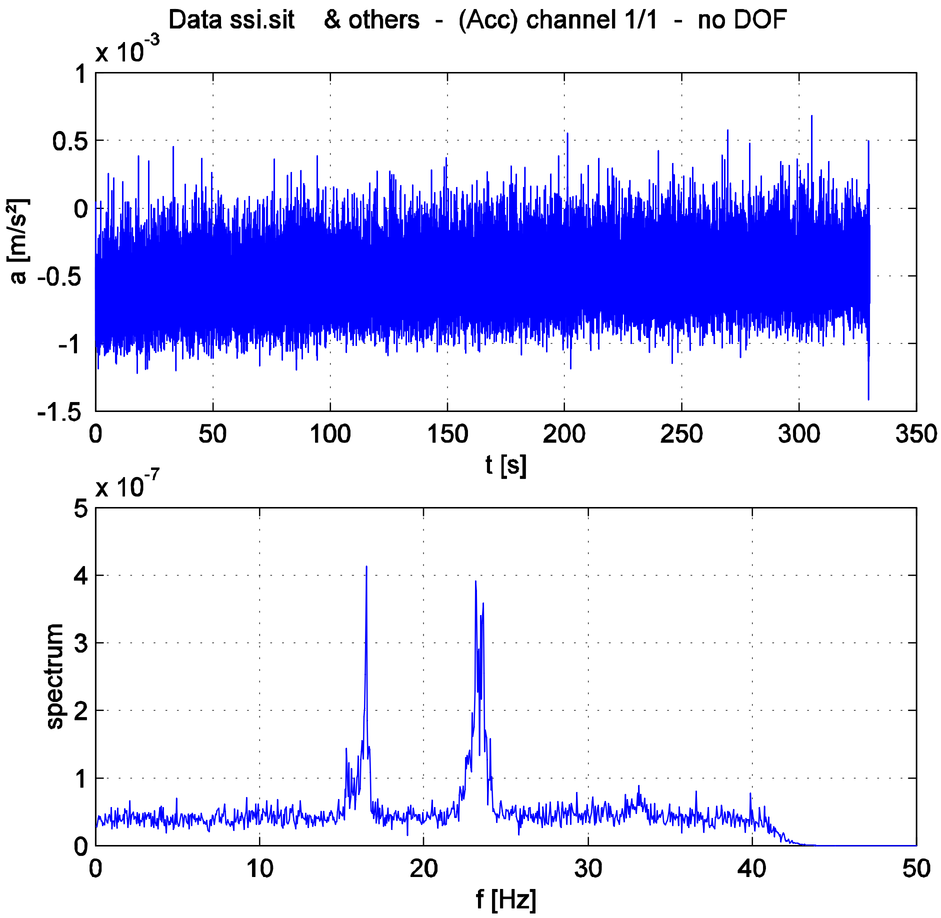


Fig. 10: Typical time history and frequency spectrum obtained by ambient testing

The data submitted in ASCII format must include accurate information about the type of structure as well as the geometric locations of all sensors in order to make identification of mode shape information possible. A general technical description concerning the hardware employed as well as sampling rate and sensitivity of sensors must be included to the data-set.

6.2.3 Shaking Table Tests

For extensive testing on a shaking table, the creation a partner network including institutes which are able to contribute to certification is required. These institutes should work close together in order to guarantee high quality results and certification and quality control on a European level. The creation of such certification network should be done in accordance with the European Certification Procedure within the SAMCO work package 4. To unify the test procedure several time histories of vibration signals should be defined which will be distributed among the partner institutes. Assessment of the tested methodology should be performed by using special evaluation forms.

It should be outlined once again if detailed certification of hardware components is required, shaking table tests are the only one possibility to conduct these tests reasonable and objective.

Fig. 11: Shaking table of Arsenal Research

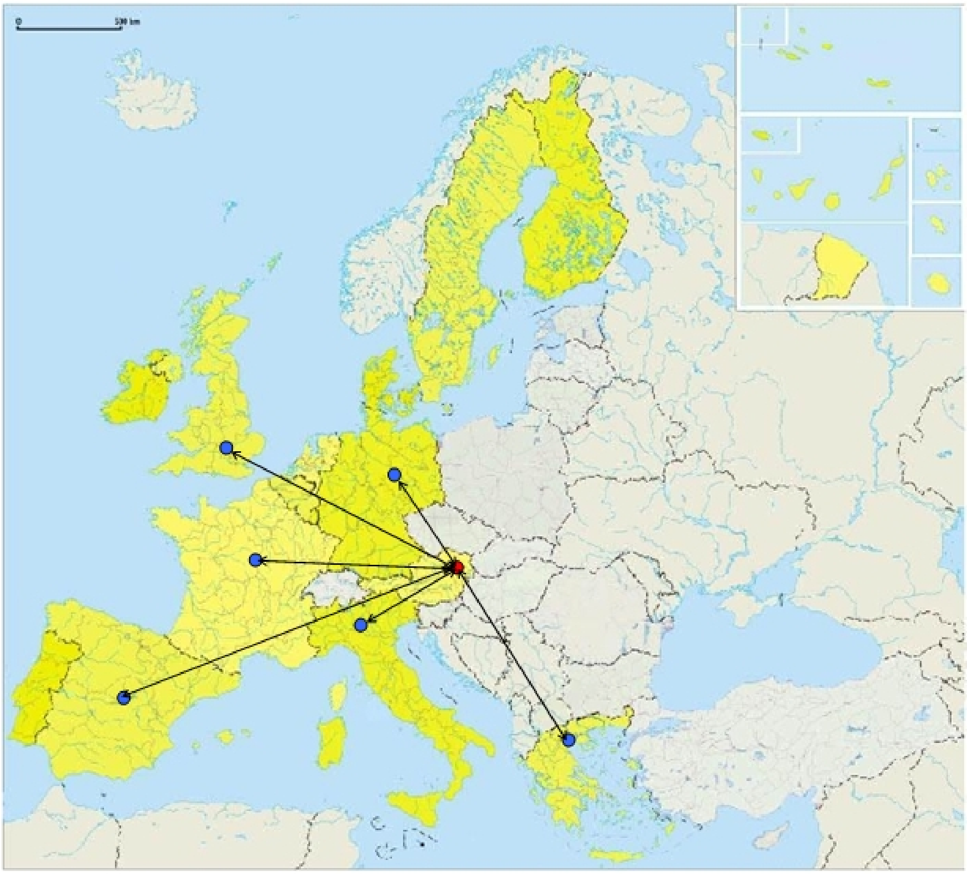


Fig. 12: Outlook to a European Network of local certification agencies

This report comprises a draft document for implementation of a certification strategy within the SAMCO network. The success of the project is strongly dependent from the participation of all partners in order to define a well-known and later on recognised certification procedure. To attract attention among the structural dynamics industry it is required to promote the certification scheme whenever possible.