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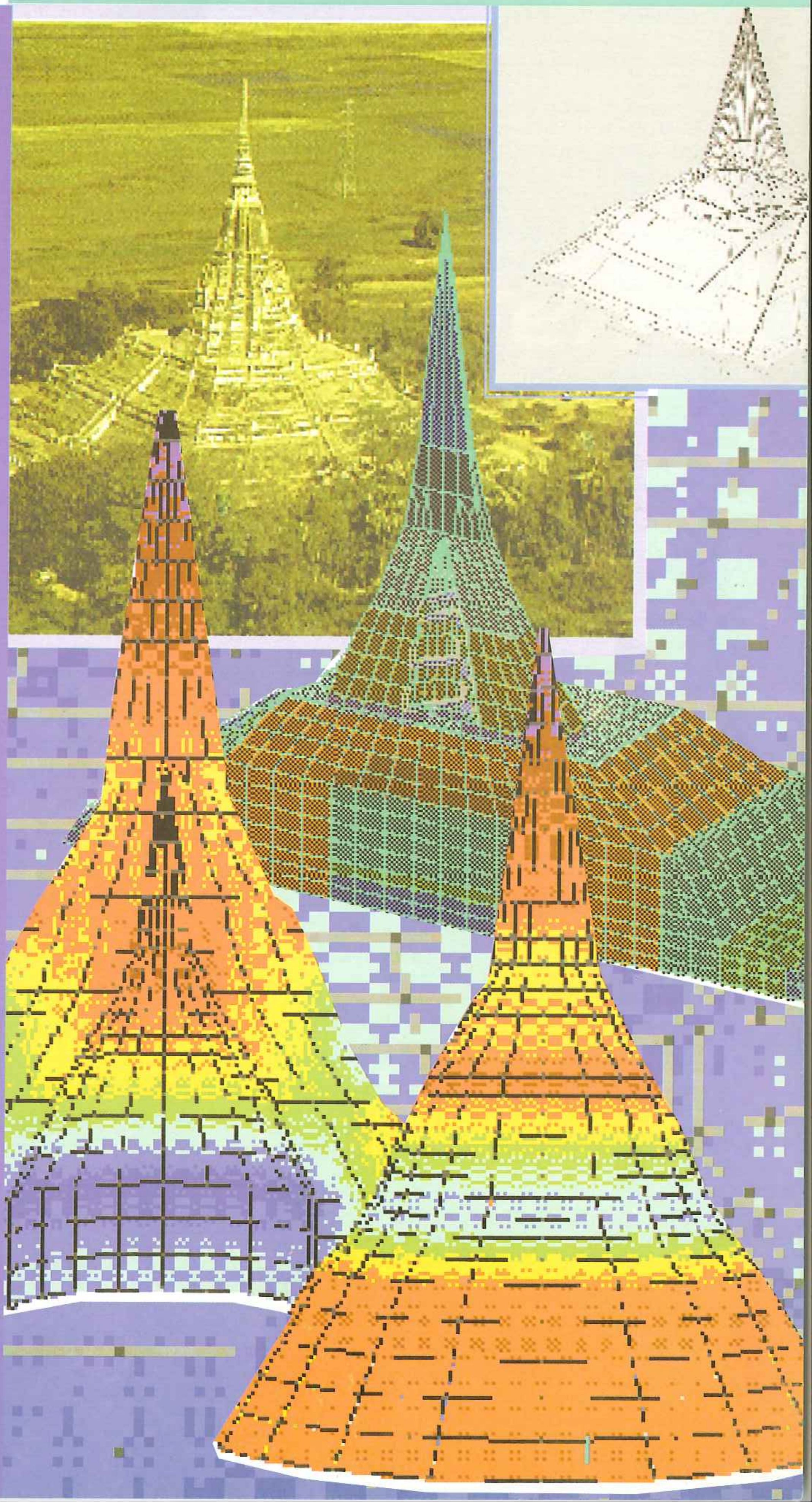

Bulletin for The International Association for Computational Mechanics

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editorial

Computational Mechanics and the Worlds of the Large and Small

Read any book on Computational Mechanics and you will find that it focuses on technological and scientific problems governed by the theories of classical physics, such as elasticity, fluid mechanics, electromagnetics, etc. Great success has been achieved in these areas but in the future it is apparent that Computational Mechanics will also become a dominant methodology in the worlds of the large and small, namely, the theories of gravitation and quantum phenomena.

Computational activity in these areas is already advanced and rapidly increasing, especially in the world of the small. Nanotechnology is one of the hottest research areas to emerge in years. Classical continuum modelling proves inadequate at very small scales, but full quantum modelling numbers of simple atoms, of the order of thousands. This is not adequate to deal with even the smallest features of electronic devices, but at the rate computer speed and storage are increasing, it is anticipated that ab initio modelling will become a practical engineering analysis tool in less than 20 years.

In the meantime, efforts are underway to synthesize continuum modelling with various levels of atomic, molecular and ab initio modelling in a "multiscale" format. The necessity and desirability of multiscale approaches have made them a popular theme in current research.

At the other end of the spectrum of length scales are problems of cosmology which are governed by Einstein's theory of relativity. Recently, experimental evidence has indicated that the universe is not only expanding but it is expanding at an accelerating rate! Much of what is presented in physics texts is in conflict with this discovery. Einstein's equations are incredibly complex and can be solved in closed form in only the simplest cases, thus necessitating a numerical approach.

In addition to cosmological issues, there are many other topics of scientific interest governed by the theory of relativity, such as black holes, gravitational waves, etc. Relativity is an intrinsically four-dimensional theory of space-time and thus requires a space-time solution methodology. Space-time methods have also begun to attract attention in more traditional areas due primarily to recent progress made with the "discontinuous Galerkin method". It is very clear that the repertoire of computational mechanics methodologies will need to be expanded to deal with the problems of the large and small.
Who will be the first to develop a good, four-dimensional, unstructured, simplex mesh generator?
Who will be the first ab initio modeler to simulate the formation of diamonds by subjecting carbon to high pressure?

Thomas J. R. Hughes
IACM President

GeoFEM
Multi Purpose Parallel FEM for

by
Genki Yagawa
University of Tokyo
Hiroshi Okuda
Yokohama National University
Hisashi Nakamura
Research Institute for Information Science & Technology

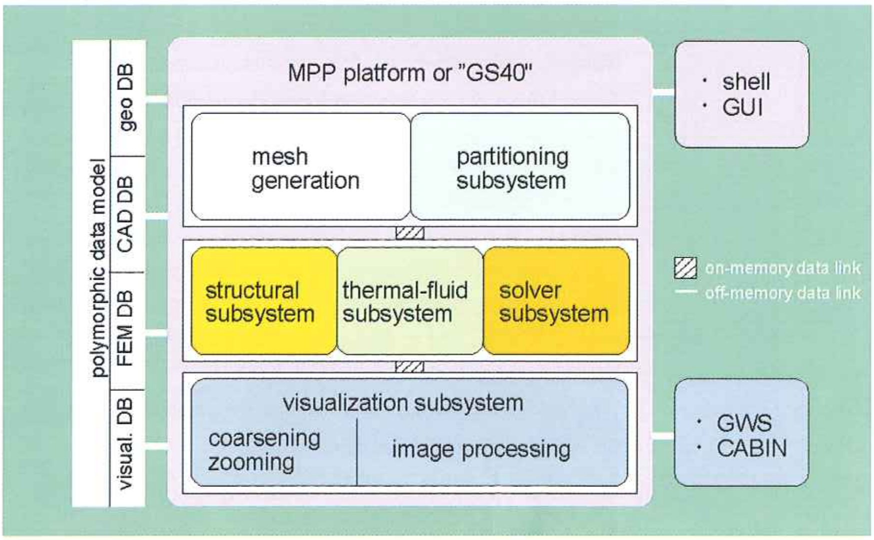
GeoFEM Project Overview

The Science and Technology Agency, Japan, has begun an Earth Simulator project from the fiscal year of 1997, which enables the forecast of various Earth phenomena through the simulation of virtual Earth placed in a supercomputer. The specific research topics of the project are as follows:

1) Development of a high performance massively parallel processing computer: 'Earth Simulator (GS40)' (40 Tflops / Peak Performance, 10 TB Memory);
2) Modelling of atmospheric and oceanic field phenomena and high-resolution simulations;
3) Modelling and simulation of solid earth field phenomena;
4) Development of large-scale parallel software for the Earth Simulator.

GeoFEM deals with the topics 3 and 4 of the above. The challenge for long-term prediction of the activities of the plate and mantle near the Japanese islands through the modelling and calculation of the solid earth analysis, including the dynamics and heat transfer inside the Earth, will be tackled.

Figure 1:
System configuration of GeoFEM/Tiger



GeoFEM was planned to develop the system in the following two phases:

Phase I : GeoGEM/Tiger (1997-1998): Multi-purpose parallel finite element software, which may be applied to various fields in engineering and sciences as well as becoming the basis for the solid earth simulator to be developed in Phase II.
Phase II : GeoFEM/Snake (1999-2001): A software system optimized for GS40 and specialized for the simulation of solid earth phenomena such as mantle-core convection, build-up of tectonic stress, deformation of plates and seismic wave propagation.

Figure 1 shows the system configuration of GeoFEM/Tiger, which consists of 'subsystems' for solver, structural analysis, thermal-fluid analysis, visualization etc. Detailed information including source codes and related documents of GeoGEM/Tiger can be obtained from the web site http://geofem.tokyo.rist.or.jp

Parallel and Vector Performances

GS40 has a hierarchical configuration, i.e. consists of 640 nodes connected by the single-stage crossbar network, each of the nodes consisting of 8 vector processors. Parallel and vector performances of GeoFEM have been investigated in preparation for the optimum use of GS40.

An 100 million DOF (107,811,000 DOFs) elastic analysis in three dimensions is carried out on a simple cubic model. The analysis is performed using 1,000 PEs on Hitachi SR2201 (1,024PEs, 256MB/PE) at the University of Tokyo. ILU(0)-CG solver iterations and the elapsed time are 1,607 and 1.4 hours, respectively. Based on the (estimated) elapsed time using 1 PE, speed-up 612 (Efficiency 61.2 %) is attained. The work-ratio is kept to be over 96 %, which implies that the communications among PEs are efficiently performed.

Figure 2 shows the elapsed time required to solve the simple cubic model varying the size and the number of PEs.

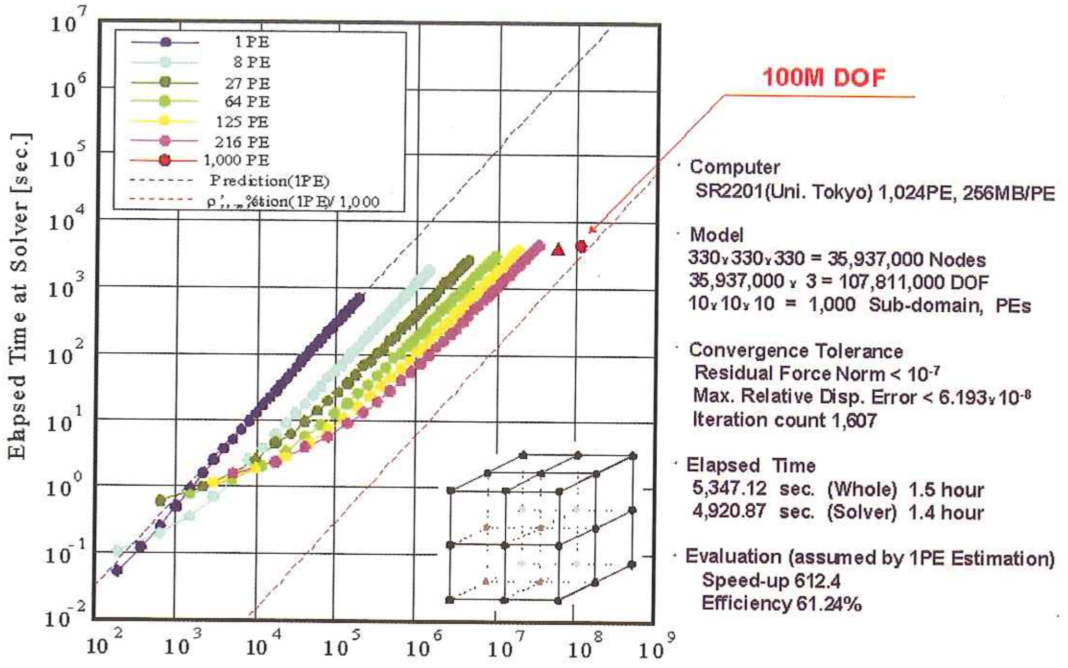


Figure 2: *Elapsed time required to solve a simple cubic model up to 100 M DOF*

In the Snake phase, development should be more focused on the performance-tuning for GS40 and solid earth simulations. As the first stage of the performance-tuning, the parallel iterative solver is vectorized. A one million DOF Poisson equation is solved by the ICCG method with RCM ordering on NEC SX-4 in JAERI/CCSE at the speed of 720 Mflops (Peak Performance 2GFlops).

Plugable Design

GeoFEM, comprised of many 'subsystems' such as the structural / thermal-fluid dynamics and the visualization, is a software system which targets to simulate geophysical problems as a whole. This system is also designed to be the basic platform for the trial of geophysical programs, thus the interface of the sub-systems must be obvious. Therefore, each sub-system is designed to be plugable (*Fig.3*), meaning that each sub-system program is easily replaceable with other programs of the similar nature.

The plug system is designed to perform most of the communications among processors implicitly in the GeoFEM system code, not in the user code. This enables each parallel analyzer code to have a similar appearance to the sequential code, and hence any special skill to write parallel programs is not required to develop analyzers.

" ... development should be more focused on the performance-tuning for GS40 and solid earth simulations."

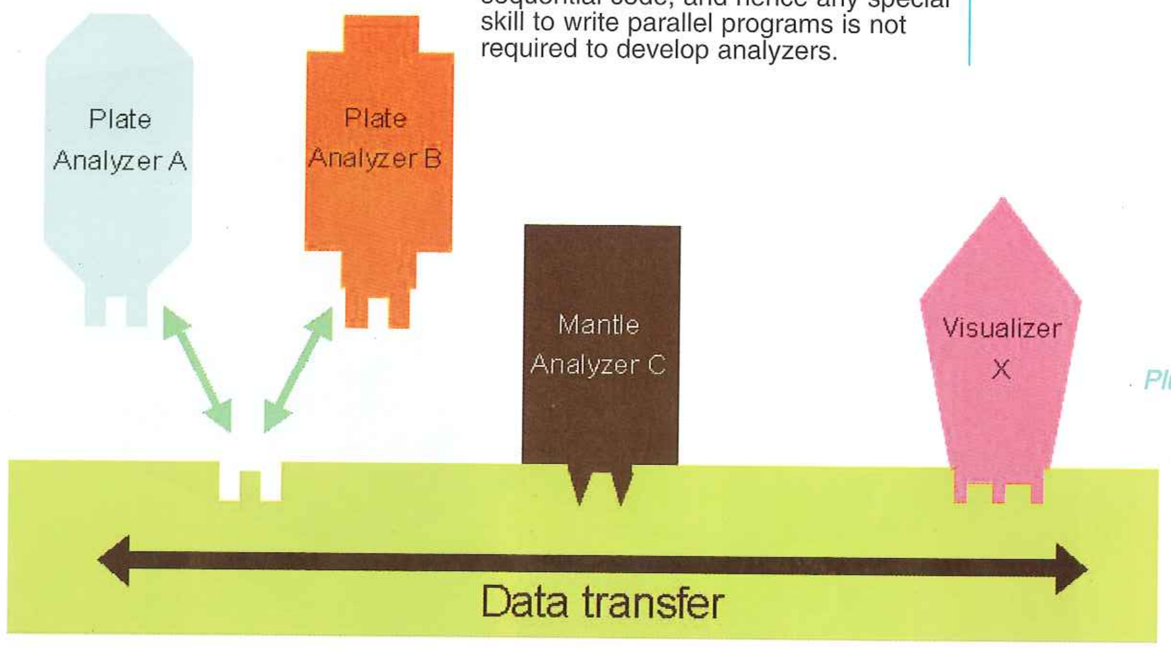


Figure 3: *Plugable design*

"... two procedures will be developed in order to obtain a more stable convergence."

To accomplish these plug features of GeoFEM, two major functions are designed and implemented.

Communicator
The 'glue' programs, which connect subsystems of GeoFEM, are called the 'communicator'. Communicators are replaceable in accordance with the computational platforms (especially the communication medium between the subsystems). The communicator program currently supports the communication between an analyzer and the visualizer. This communicator function will be extended to support the communication among various analyzers, i.e., support the 'coupler' functions for multi-disciplinary computations such as the analysis of interactions among plate motion, crustal deformation, faults rupture and wave propagation.

Localized parallel operation
In parallel computing, the entire data set should be partitioned into small local data sets in order to efficiently perform local operations. In GeoFEM, the entire region being partitioned, communication tables between neighbouring partitions are also in the local data. GeoFEM provides partitioners by Greedy, RCB and RSB methods. Interface for METIS code is also available. In GeoFEM, finite element code on each PE assembles coefficient matrix locally and calls the parallel iterative solver. Global operations only occur in the solver implicitly during dot product, matrix-vector product and preconditioning computations.

Parallel Solvers

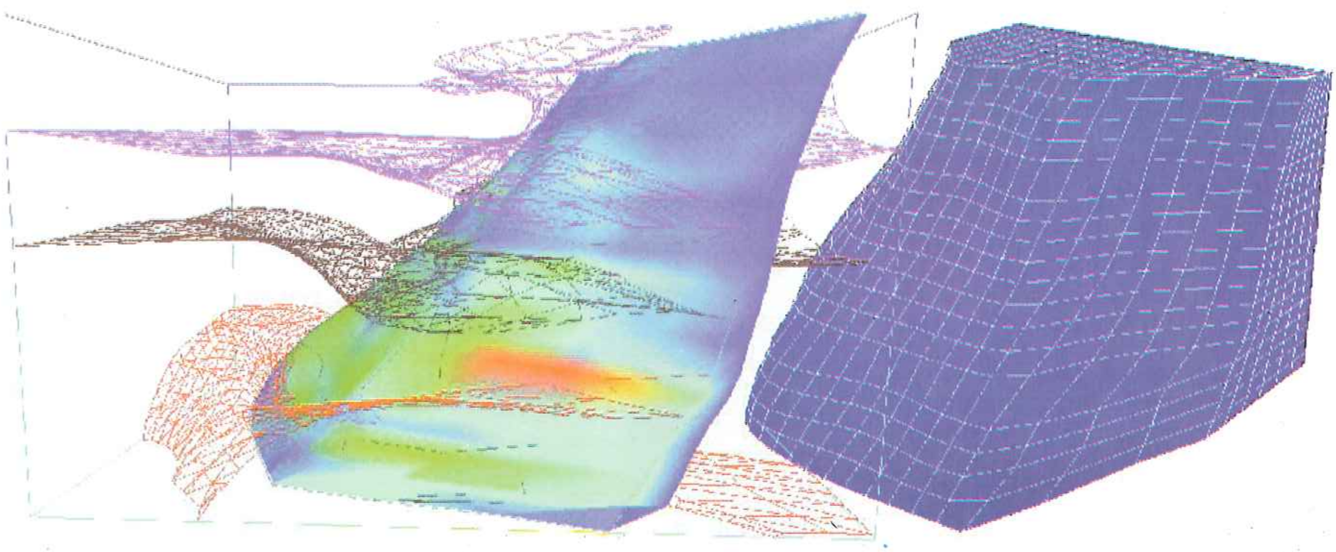
In a large-scale scientific computing, linear sparse solvers are one of the most time-consuming processes. In GeoFEM, various types of preconditioned iterative methods (CG, BiCGSTAB, GPBiCG, GMRES) are implemented on massively parallel computers. Localized ILU(0) preconditioning methods provide data locality on each processor and good parallelization effect.

In the Snake phase, two procedures will be developed in order to obtain more stable convergence. One is the new preconditioning methods with deflation. The other is multigrid or multilevel method for global smoothing. Hierarchical data structure in grid adaptation is utilized for formation of coarse grid systems. "DRAMA" developed by ESPRIT/EU is also implemented as a repartitioning tool for grid adaptation through the collaboration with NEC Europe.

Large Scale Structural Analysis for Solid Earth

Solid earth phenomena to be simulated by the structural sub-system are lithospheric plate motion and earthquake wave propagation. Large scale and complex non-linearity must be considered in order to solve such problems. As the first order approximation, these problems may be solved with a linear system of equations. In GeoFEM/Tiger, linear elastic module and wave propagation module are implemented on massively parallel computers.

Figure 4: *Analysis of faults around the Japanese islands (normal contact force and equivalent stress)*



An 100 million DOF elastic analysis (see section 2) was one of the targets of GeoFEM/Tiger. In the Snake phase, a more effective structure analysis module on GS40 will be developed for analyzing the super large-scale problems, i.e. 10 billion DOFs for the maximum case.

Complex Structural Analysis for Solid Earth

Material and geometrical non-linearity, time dependency, multi-phase dynamics and discontinuity are the complexities to be considered in the solid earth simulations. In GeoFEM/Tiger, parallel contact analysis module using the augmented Lagrangian method is implemented for the large scale faults analysis.

In the Snake phase, to tackle more complex solid earth dynamics, simulation models for earthquake generation process, earthquake cycle, faults rupture dynamics and long-term crustal deformation will be developed.

Figure 4 shows sample analysis of faults around the Japanese islands (normal contact force and equivalent stress).

Thermal-Flow Analysis for Solid Earth

In the thermal-flow sub-system, large-scale natural convection computations are performed enjoying the high performance parallelism of GeoFEM. For simulating the mantle convection phenomenon, which is the movement of the various materials as a result of the high temperature in the inner part of the earth, sets of complex nonlinear equations with temperature dependent reology or viscoelastic models should be considered. In the Snake phase, mantle convection as well as core dynamics will be tackled by incorporating the such models.

Figure 5 shows the natural convection in double sphere region.

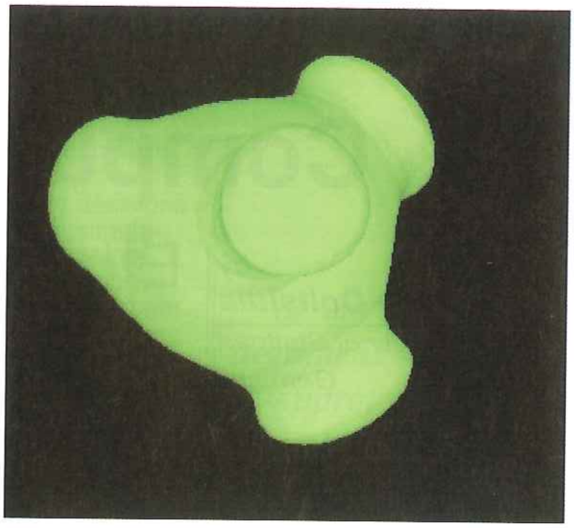


Figure 5: *Natural convection in double sphere region*

Comprehensible Volume Visualization

The concept of solid fitting was proposed to unify the indirect and direct approaches to volume visualization, which is intended to provide an intuitive and effective means to explore the inner structures and complex behaviour of various 3D volumetric data sets arising from the GeoFEM subsystems for numerical analysis.

A parallel code to extract simplified polygonal representations for interval volumes as a generalized isosurface from large-scale unstructured volumes has been developed. In addition, a 3D field topology analysis is utilized for automating transfer functions design aiming at comprehensible data exploration without unnecessary iterations of computationally-expensive re-rendering of volumes.

Figure 6 compares images of an analytic volume, which are rendered with normal transfer functions and optimized ones based on the proposed volumetric topology analysis. ●

"... 3D field topology analysis is utilized for automating transfer functions design aiming at comprehensible data exploration."

Figure 6: *Images of an analytic volume, (a) rendered with normal transfer functions, (b) based on the volumetric topology analysis*

Modelling Issues in Computational Mechanics

by
Ioannis Doltsinis
University of Stuttgart
Germany

Engineers usually receive an education based on smooth mechanics as regarding continua and structures, and they enjoy acquiring the principles of actio et reactio for a system, developing solutions to problems in mechanics and approaching topics of practical interest. The pleasure felt when determining a solution is greater when more uncertainty is involved in circumstances. At this place it appears meaningful to distinguish between the pre- and the computer era. Before the advent of modern computers, the main concern of engineers and scientists has been the balancing between feasibility and practical significance of analytical solutions.

The constituents of a numerical model intended to represent the actual system under consideration are: the underlying physics and mathematical formalism on the one hand, the discretized description and numerical solution algorithm along with soft- and hardware on the other hand. Each of the above elements may hide sources of uncertainty concerning the computer simulation results. The tasks of adequately accounting for the participating physics and their mathematical description are not new. But computation allows for trials, assessing the significance of various phenomena. The mathematical formalism also encompasses the numerical solution algorithm and the computer implementation. The discretized representation in space and time of the system under investigation presumes a certain degree of imagination regarding the expected response. In finite element methodology, automatic mesh generation techniques aim at reducing input relying on knowledge, experience or the intuition of the analyst, although this is still often desirable. Even mesh modification, adaptive to certain criteria depending on the solution, should allow the analyst to intervene. Last but not least, the code or coding and hardware may imply pitfalls with respect to functionality and arithmetics.

Figure 1: *Facing uncertainty. (Courtesy GKC)*

Regarding solids and structures, physics may refer to the phenomena occurring within the system, such as mechanical and thermal, the material response being it elastic or inelastic based on various approaches, as well as the environmental conditions defining actions on the boundary of the structure, or determining the extent of the system to be considered. The mathematical model may be linear or non-linear, quasi-static or accounting for inertia effects. Similarly in fluid

The employment of computational methods for the solution of engineering problems is expected to diminish the distance to industrial practice but introduces, at the same time, several uncertainties.

dynamics, with particular issues concerning viscosity, turbulence, chemical reactions, and catalytic effects for instance.

Discretization by finite elements comprise the selection of the finite element type and the design of the computation mesh. Evolutionary, resp. dynamic processes require, in addition, choice of the integration scheme and the temporal incrementation. Realization in the computer implies availability or creation of adequate software, providing the necessary numerical algorithms.

Hardware can affect the performance of the simulation model in both computational speed and quality of results. Especially when the model contains ill-conditioned constituents, such as penalty forms of material rigidity, contact etc. the arithmetics of the processing unit is decisive for quality of results.

Verification of the computational model is clearly necessary in order to ensure that it behaves as expected, while evaluation determines the degree of satisfaction in representing the response of the system. A successful computation model can extend the range of an application considerably beyond that of analytical solutions.

As the subtility of engineering decisions based on results of numerical simulations of physical processes increase, the request on the validity of the computational model is strengthened. The difficulty of validation increases with the complexity of large scale industrial problems. Probably the most adequate way of examining the validity of a computational model for an actual system is comparing data from experimental measurements. At this stage we have to realize that our knowledge on the system is incomplete, and that specification requires statistical description accounting for fluctuations in the input data.

"... our argument suggests to appropriately pay attention to the variability of the data."

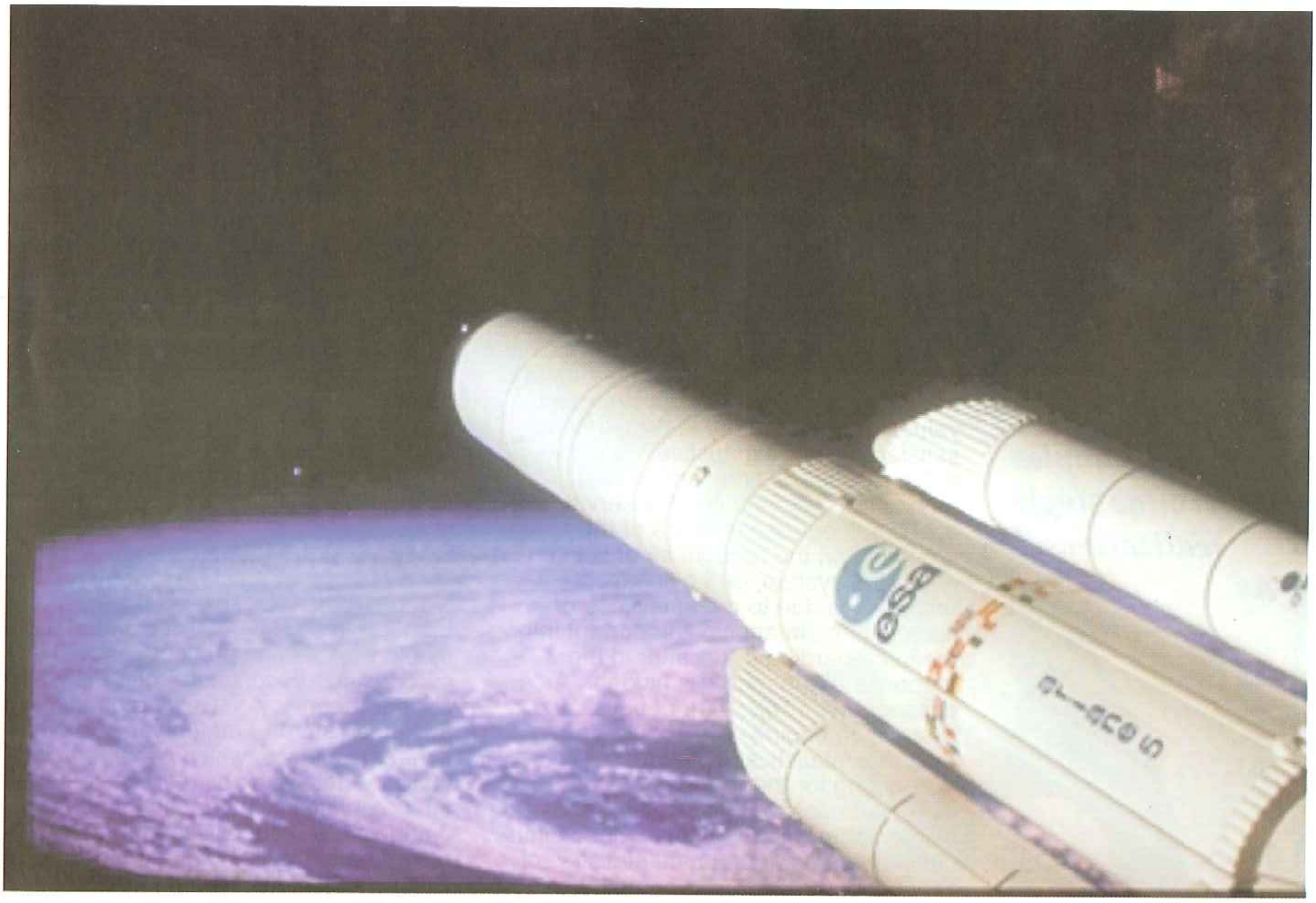


Figure 2: *Ariane V, partial view.*

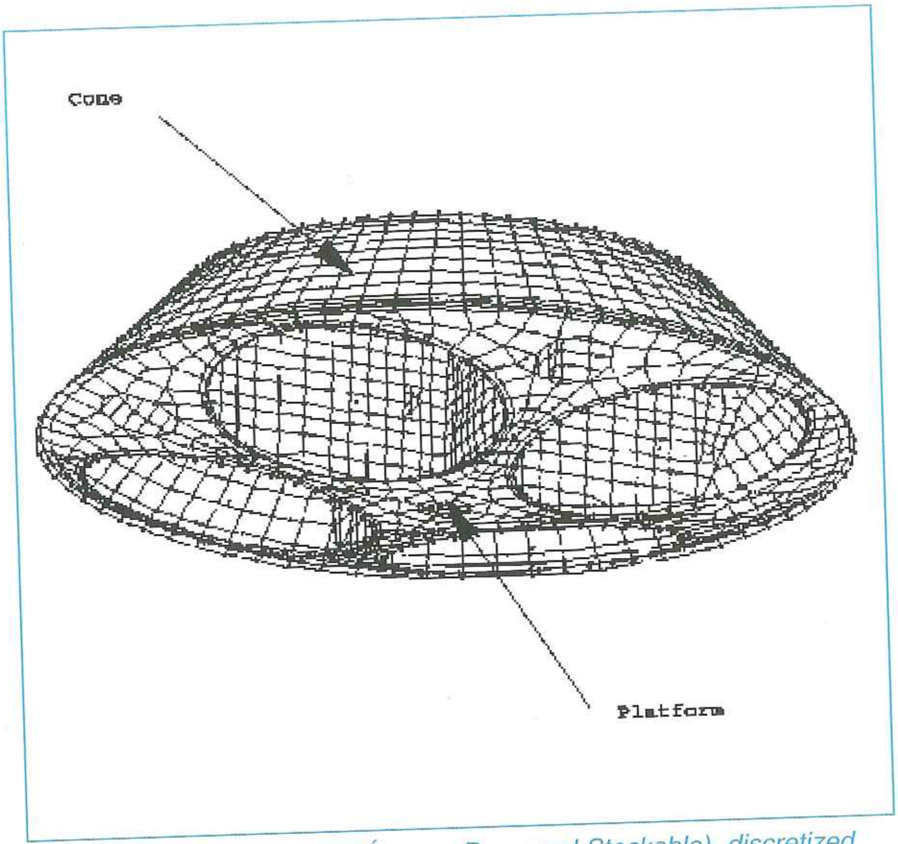


Figure 3: EPS-structure (Étage a Propergol Stockable) discretized by finite elements (CASA Space Division, Madrid).

" ... the implications of scatter have to be accounted for in the input and the output quantities of material samples that determine single realizations."

Equally, comparison of the computational output with the experimental measurements has to be based on statistical inference, and since we may be interested in several response quantities that do not vary independently, the subject is one of multivariate statistics. It is worth noticing that the comparison of results of single computations, based on nominal values of the random input and/or system parameters with mean values from laboratory tests, is neither satisfactory nor exhaustive. Nominal value results are comparable with means from experimental observations, only if a linear dependence of the response on the random input is inherent to the system, or if a linear response is due to the smallness of fluctuations. In addition, important information regarding the scatter in the response of the model is hidden. As a consequence, validation of physical systems in engineering should be based on statistical techniques, accounting for the randomness of the input variables that specify the numerical computer model. Monte Carlo simulation provides appropriate statistics of the response quantities; comparison with experimental sampling gives the degree of confidence in the model.

What is true for the experimental set-up in the laboratory is inherent to any physical system in engineering. System parameters, like material properties, geometry and dimensions of structural components will, as a rule, exhibit scatter to a certain extent within a single sample, as well as between different samples. This introduces uncertainty in the response of the structural system independently of any randomness in the acting loads or other boundary and initial conditions that complement the input to the system. For instance, the thickness of a sheet material which constitutes a shell-shaped component or which is to be subjected to a forming operation, exhibits fluctuations with respect to its nominal value. Lack of complete knowledge suggests specification as a random field. Similarly, variations in the microstructure of the material influence the behaviour. Microstructural parameters may enter the material constitutive law directly as does the grain size in the description of superplastic behaviour, or they remain hidden and merely the associated variation in the material characteristics is registered as a result. Depending on the sensitivity of the system under investigation, and on the degree of variability of the input parameters, the consequences for the response can be significantly beyond randomness of the output if branching is possible.

The issue of selecting the structural material in a design is currently of topical interest in automotive engineering, where advantages and disadvantages of employing aluminium in place of steel are discussed and investigated. In general, structural materials do not differ only with respect to their nominal properties but also with respect to the scatter that the properties exhibit. Therefore, an assessment of alternative materials for the structural design based on statistical data and associated analysis, may lead to conclusions different to performance comparisons based on nominal values. The same applies to performance comparisons between different designs, and more generally to design improvement resp. optimization, which actually implies decisions accounting for the given uncertainty.

Evidently, our argument suggests paying appropriate attention to the variability of the data [1]. This is, of course, a matter in reliability analysis and of wide use in engineering practice, as well as introducing educational programs which appear meaningful. Relying on the advanced state of maturity in computational mechanics, which considerably facilitate determining solutions to complex problems with varying input and extension to probabilistic treatment based on statistics, is straightforward. Even when statistical data for the input parameters are absent and cannot be acquired, the theory of fuzzy sets offe a mean to proceed further. Sampling strategies from statistics have proved useful in handling deterministic problems as well. Here we recall that, unlike analytical solutions, numerical results from the execution of a computer run represent a single realization which refer to a certain set of input parameters. Analysts are interested in exploring the response of the system to variations of the input data within a range beyond local sensitivity analysis. For this purpose, parameters are given different values more or less systematically, and the response is recorded, but frequently conclusions cannot be drawn because relevant information is ultimately missing. This particularly occurs when the impact of several parameters on the system have to be considered. Computer run interpretation, as a numerical experiment, allows utilization of experimentation strategies in planning efficient sampling [2]. Moreover, such techniques can also be used in numerical product or process optimization.

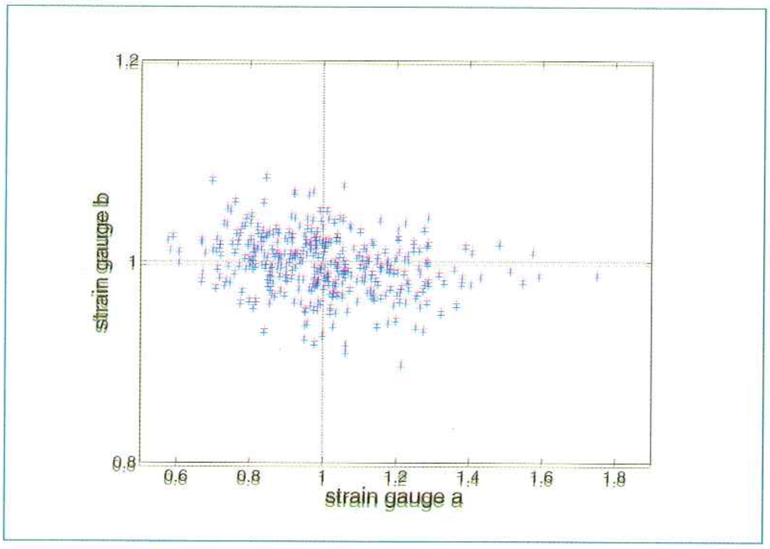


Figure 4: *Computed strains at two measurement positions. The scatter is a result of randomness in the thicknesses and elastic moduli that enters the Monte Carlo simulation [1]. The cloud in the bivariate plot suggests that the two selected output variables are correlated weakly.*

Figure 5: *Porous ceramic filter support and maximum principal stress due to fluid pressure in the channels.*

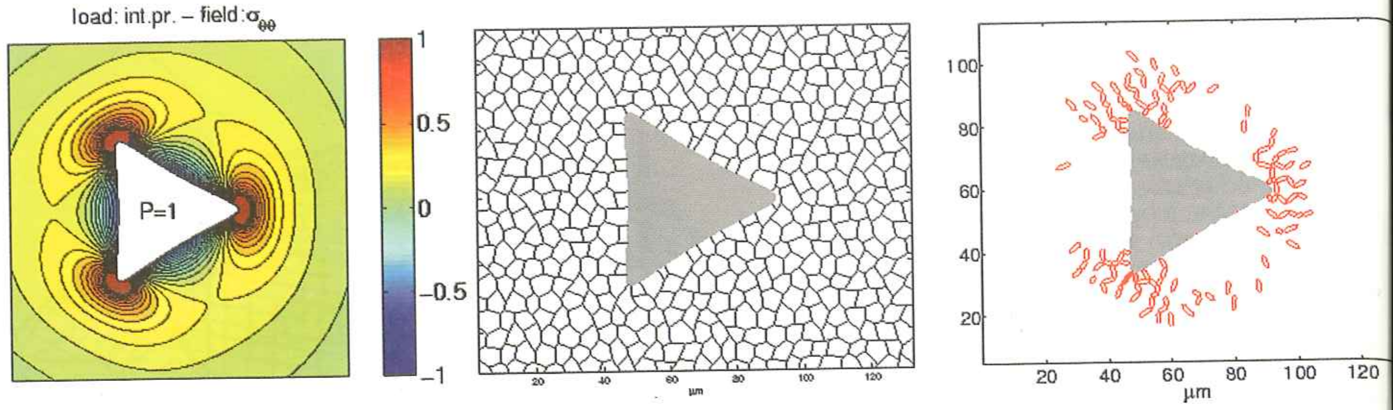


Figure 6: *Isolated pore under internal fluid pressure. "Circumferential" stress, and grain boundaries prone to fracture (right).*

" Multiscale simulations deserve particular attention with regard to overall approach and details of realization as long as the different levels of interest can not be separated uniquely. "

Whenever we feel we are not in a position to establish rules from observations at a certain level, or are interested in background reasoning, we recall that we may register the collective result of events or processes taking place at a lower level and measured on a finer scale. The statement is widely applicable, but here we have in mind the deduction from the microstructure of material properties on the continuum level. Such a necessity exists when dealing with the design of advanced composite materials and investigating the inpact of the constituents on the macroscopic response, or when the effect of the microstructure characteristics of conventional materials has to be explicitly known in order to account for variations. Micromechanics aims at studying the significance of the microstructure for the macroscopic response under various conditions including damage and failure. Thereby, continuum concepts are employed at the microscopic level. Analytical solutions are restricted by their very nature, and therefore numerical approaches offer themselves for the determination of the material response in the microscale. Transition to macroscopic properties of the material requires careful selection of the sample microstructure and definition of the boundary conditions. An efficient strategy for the variation of parameters within the range of interest helps to obtain the requested information with a minimum in computation effort.

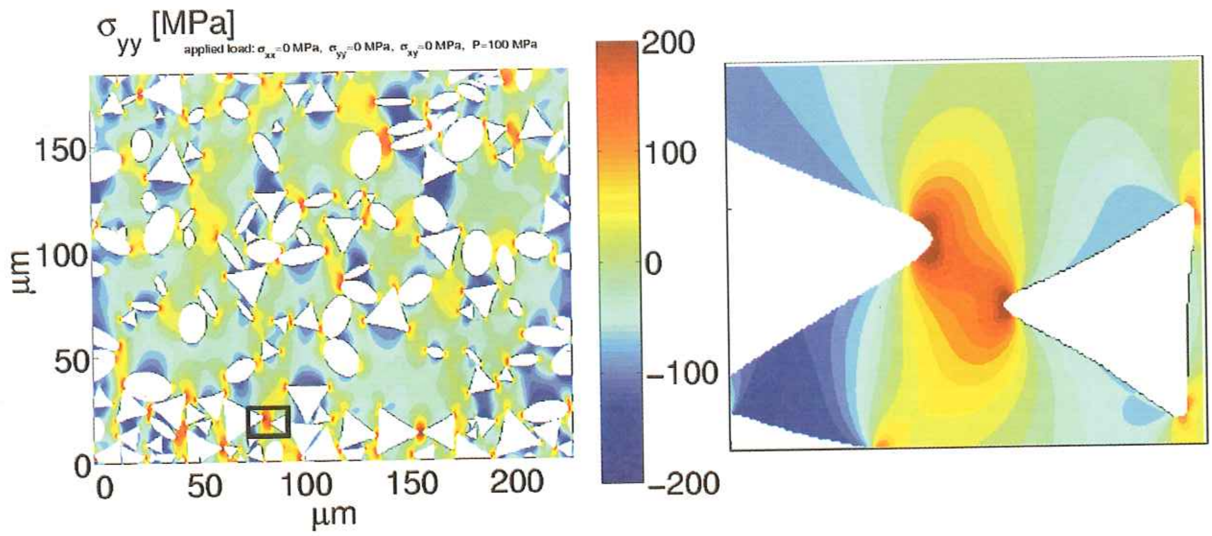


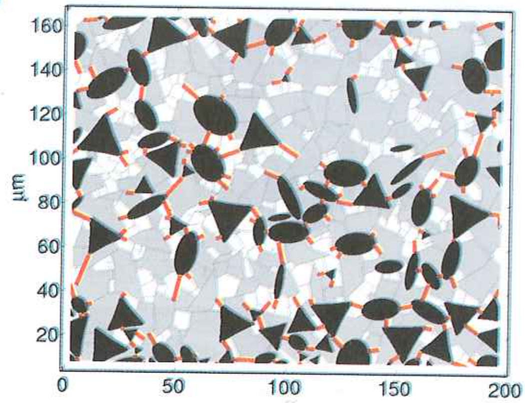
Figure 7: *Vertical normal stress in microstructure due to internal pore pressure. Magnified detail shows critical conditions in the ligament.*

Conventionally, a description of the microstructure of the material is based on statistical data. Therefore, the implications of scatter have to be accounted for in the input and the output quantities of material samples that determine single realizations [3].

For illustration, we refer to brittle materials where progressive fracturing in the microstructure alters the original macroscopic properties. Modelling of the microcracking in samples of the material structure under the given conditions provides information on the state of damage as well as on the temporary, macroscopic response for use at the continuum level.

Multiscale simulations deserve particular attention with regard to overall approach and details of realization as long as the different levels of interest can not be separated uniquely. ●

Figure 8: *Appearance of microcracks.*



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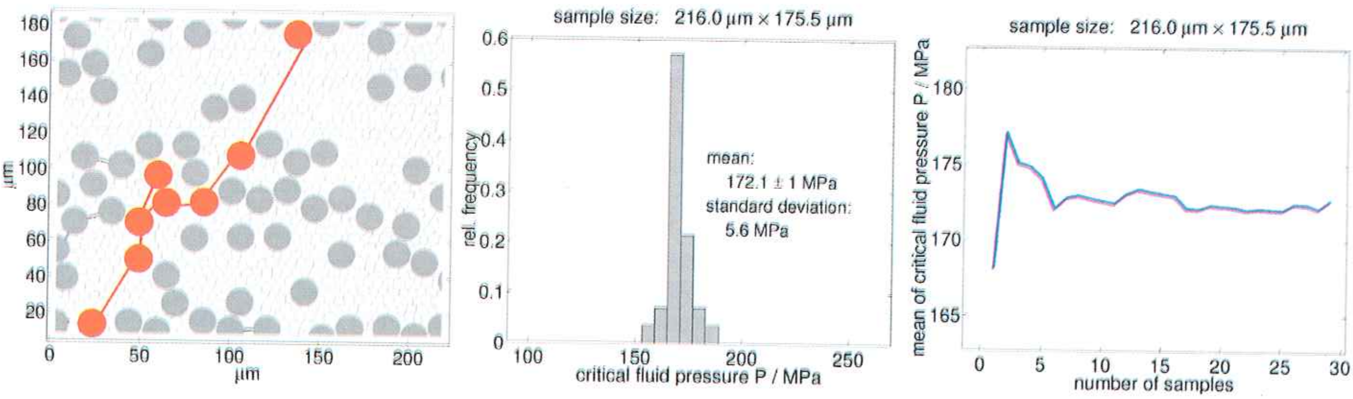
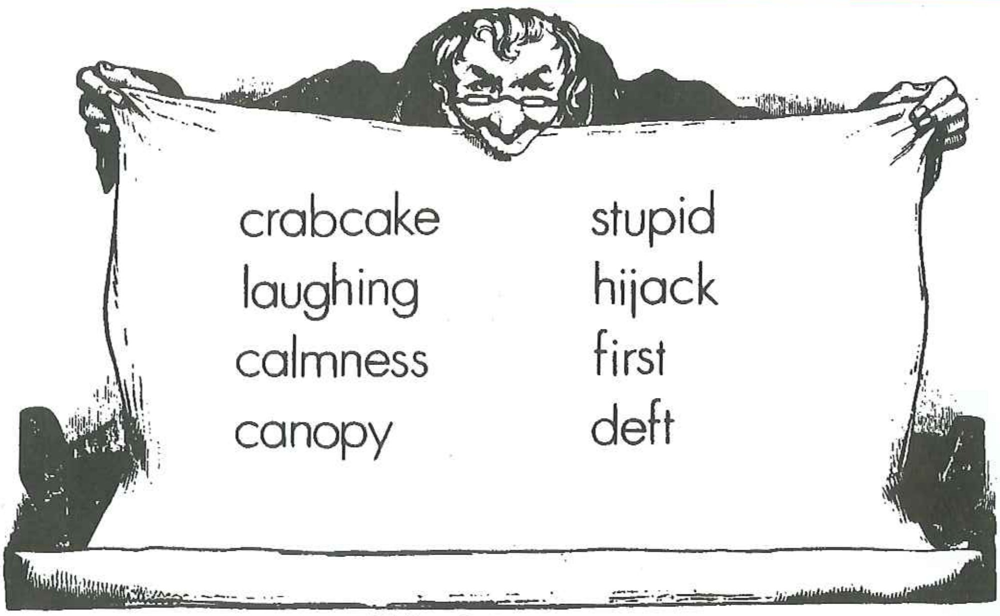
[3] E. Kröner, **Statistical Continuum Mechanics**, Springer, Berlin, 1972.

Figure 9: *Failure of the material sample by separation (red path). Variability of ultimate pressure for random positioning of the pores (middle). Dependence of the mean on the number of samples (right).*





World Puzzle

What do the eight words have in common?

Answers on page 39

Crashworthiness Simulations and Digital Prototyping at PORSCHE

Saving cost and time by FE Analyse

by
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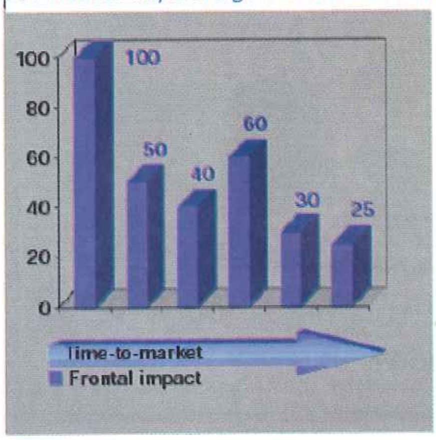
Germany

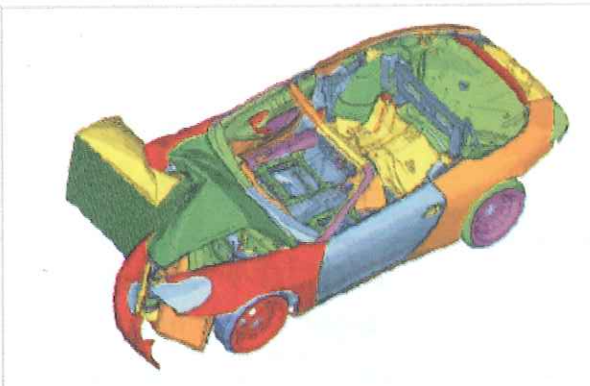
At Porsche, as in many other automotive companies, the time schedule for the development of new cars becomes tighter with each model, and digital prototyping seems to be one of the major tools to speed up the development process [1]. Besides the usual strength and vibration investigations, crashworthiness and passive safety simulations are performed. The latter types of analysis have been consistently developed further. Initially, (1982) with rather simple models with several hundreds of elements, when the focus was on the folding mechanisms and energy absorption of simple longitudinal members. Already in 1985 the first feasibility studies were carried out on the Porsche 959, looking at the driver injury risk during a frontal crash. From this early start, when the simulations had not yet influenced the development process, the situation has dramatically changed, and it is today's absolute standard at Porsche that a large number of crash simulations, with element numbers close to half a million, are performed before the first prototype is built and tested.

This is the result of a large common effort to entirely capture the development process with CAD tools from the early design stage on. The layout of the vehicle structure is entirely based on CAE data, thus the number of prototypes to be crashed is rather small, and important project decisions can be made and modified in a very early project phase. The simulation models are also adapted to the development phase. Based on the vast Porsche engineer experience within crash simulation since 1982, fairly coarse models are used in the concept phase to accelerate the basic design process, and to provide first information on potential development improvements. Within the ongoing development process, the models are refined to capture more and more details, and finally to obtain reliable prognostic data on the desired quantities. A typical simulation performed with LS-DYNA [2] is the frontal collision of a Porsche Boxster model with an offset deformable barrier shown in *figure 1*. This finally lead to a reduction of the footwall intrusion by a factor of 4, compared to the first development concept.

The cost and time saving of simulations with FE are displayed in *figure 2* and are particularly obvious for the many variations needed in the design process. At this point, it has to be noted that, a high level of reliability and robustness of the algorithms in the FE programs, concerning repetitive analyses with variations, is nowadays expected and achieved for standard types of crashworthiness analyses. In particular the contact algorithms are capable of capturing very complex situations without algorithmic failure while the finite elements have also considerably improved. E.g. the hourglass controlled underintegrated shell elements have undergone many modifications and are still the "work-horses" for most crash simulations due to efficiency reasons. They have advantages for highly distorted meshes, when the Jacobian remains positive even for strong element deformations. Nevertheless mixed interpolations such as the "Assumed Natural Shear" strain interpolation are also in use for smaller models with particular local loading.

Figure 1: *Porsche Boxster; improvement of footwall intrusion for frontal impact against offset deformable barrier*





Studies with optimization tools based on Response Surface Methodologies are also performed on a more regular basis e.g. to improve the behaviour of structural components. More importantly, Porsche currently also has the chance of studying variations concerning loading material data and structural modifications, from the uncertainty and scatter view point. This can be done based on stochastically or deterministically

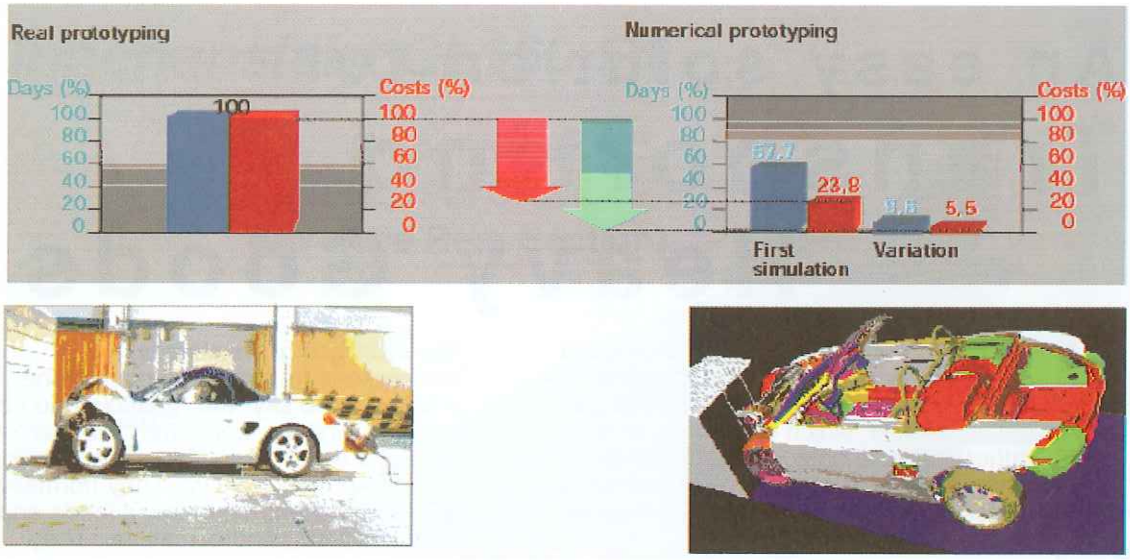


Figure 2: Cost and time saving for variations of numerical prototyping (FE model) compared to real prototyping

varying input data. First studies have shown to give valuable hints for design modifications, improving the overall robustness and strength of the structures concerning crash loading in general. A further effect on the variation studies is the chance to allow a better correlation with experimental results, compared to single analyses with fixed parameters. Thus the gap between the interpretation of experimental and simulation results can be closed in a methodological manner.

The improvement of FE programs and the crash simulation is continuously pushed by increasing demands concerning effects as including the deformation and material history of formed parts by deep drawing into the analysis. First steps have shown that even simple information about local thickness distributions leads to different local buckling behaviour, which may also, in some cases, affect the global behaviour. Other areas of high demands are non-metallic materials such as foam, glass for windows, honeycomb materials and the failure modelling of metallic and nonmetallic materials. The modelling of component connections by spot welding or bonding is also of high interest.

A high focus area at Porsche is occupant simulation for improved protection involving airbag and dummy models. Both are included in the relevant simulation studies and considerable effort is spent on continuous improvements in the modelling. The current level of refinement is visible in *figure 3* for the EURO-SID model [3] used in side impact analyses.

The highly increased number of analyses, and more detailed FE modelling, requires more computing resources and the short time frame for crashworthiness investigations leads directly to the necessity to use parallel computers. After using the SMP version of LS-DYNA for quite some time, on 2 to 4 processor machines, a current focus at Porsche is on increased usage of the distributed memory version for higher processor numbers to achieve a higher throughput.

The success of the crashworthiness simulations, and the satisfaction of high demands on the analysis tools, the complete analysis environment and, in particular, the analysis engineers, also show the development success of the FE methodology, the FE programs and the education in FE simulation. The efforts in numerical methods research and development, visible in the IACM community, are of vital importance for the automotive industry to achieve the demands concerning quality, safety and time-to-market expectations. ●

References:

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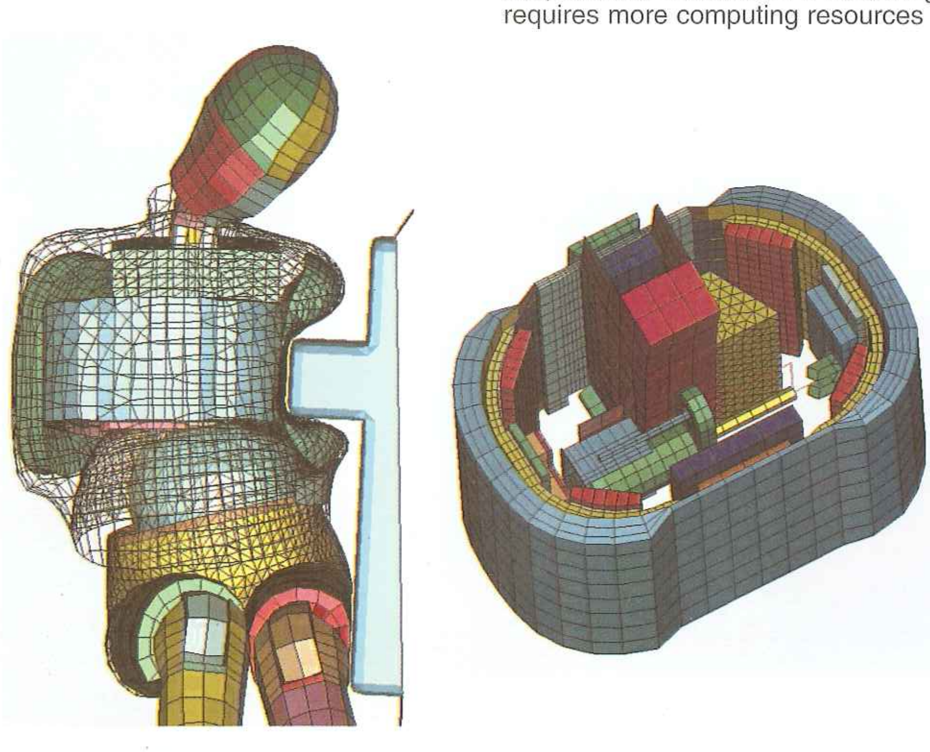

Figure 3: EURO-SID validation sled test, model detail of rib-cage

An easy solution for Transporting Heavy Goods

by
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University of Stuttgart
GACM

Airships seem to be having their great come-back today. The fascinating technological concept of the early days of this century, which died for political rather than technological reasons, is being revived. A number of international projects implying extreme technological challenges exist.

World wide projects

Cargo Lifter *[fig. 4]* is currently designing the biggest airship ever built for the transport of heavy cargo of up to 160 tons. Lockheed has presented a design for a hybrid aircraft for container transport with a payload of up to 500 tons. In the Netherlands and in South Africa we have Airship projects comparable to those of Graf Zeppelin back in the thirties. In England and Germany plans or even prototypes of airships, to be used in tourism, exist. In Japan, the US, England and Germany we find design studies for HALES (High Altitude, Long Endurance Platforms) which are permanently stationed, solar powered vehicles, at an altitude of 20000m. These will revolutionise telecommunication, earth observation and astronomic observation. The economical implications and the implications to society are, however, huge.

The strength of weakness

The reasons for the come back of the „whales of the sky" are manifold and not obvious. Airships, compared with aeroplanes, are slow, and vulnerable during take off and touch down. They normally fly in all the weather, at low altitude and depend on the wind conditions. They have low energy consumption, are well suited for long distance or even permanent operations, and can stop in the air without energy consumption. This features give strength in certain niche markets. Heavy and bulky cargo, for example, where the transport avoiding roads, harbours and reloading, makes airship transport roughly 10 times faster than classical transport. Permanent observation platforms, solar-electric powered or cruise flights seem to have a great market in future.

The system

The lift of airships is created by the buoyancy of a gas, lighter than air, independent of the speed. Since one cubic meter of Helium, the typical, non-flammable lifting gas, carries about one kg of mass, the Airship body becomes voluminous. CargoLifter has,

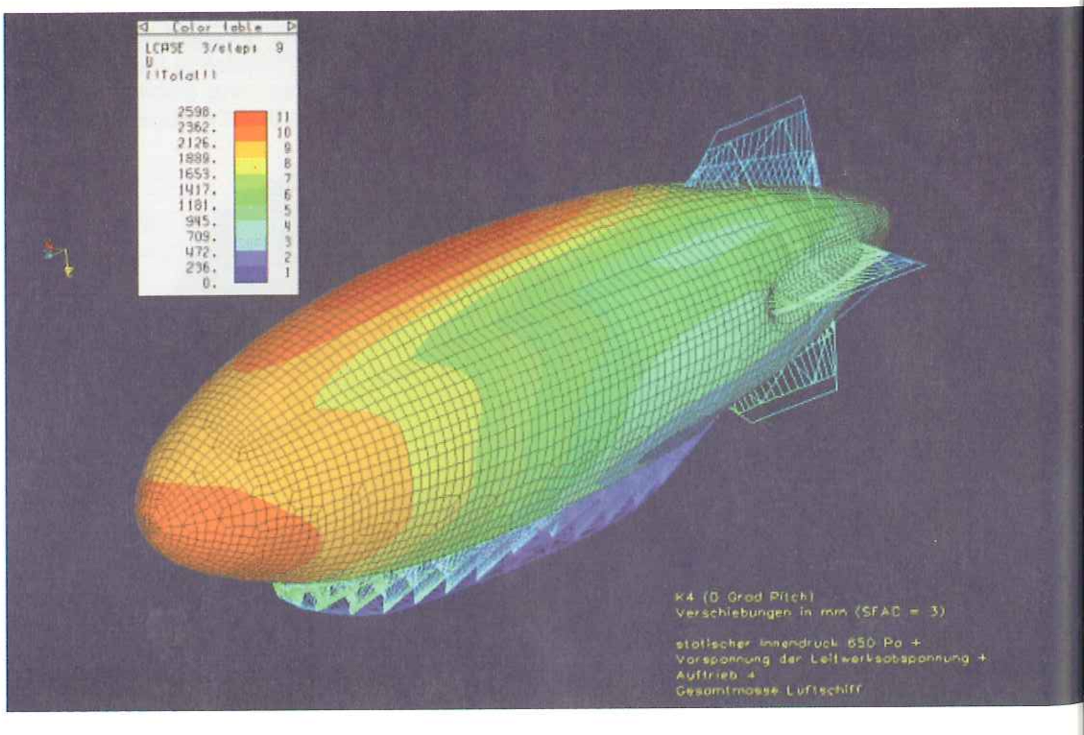

Figure 1: A Computer Model of an Airship

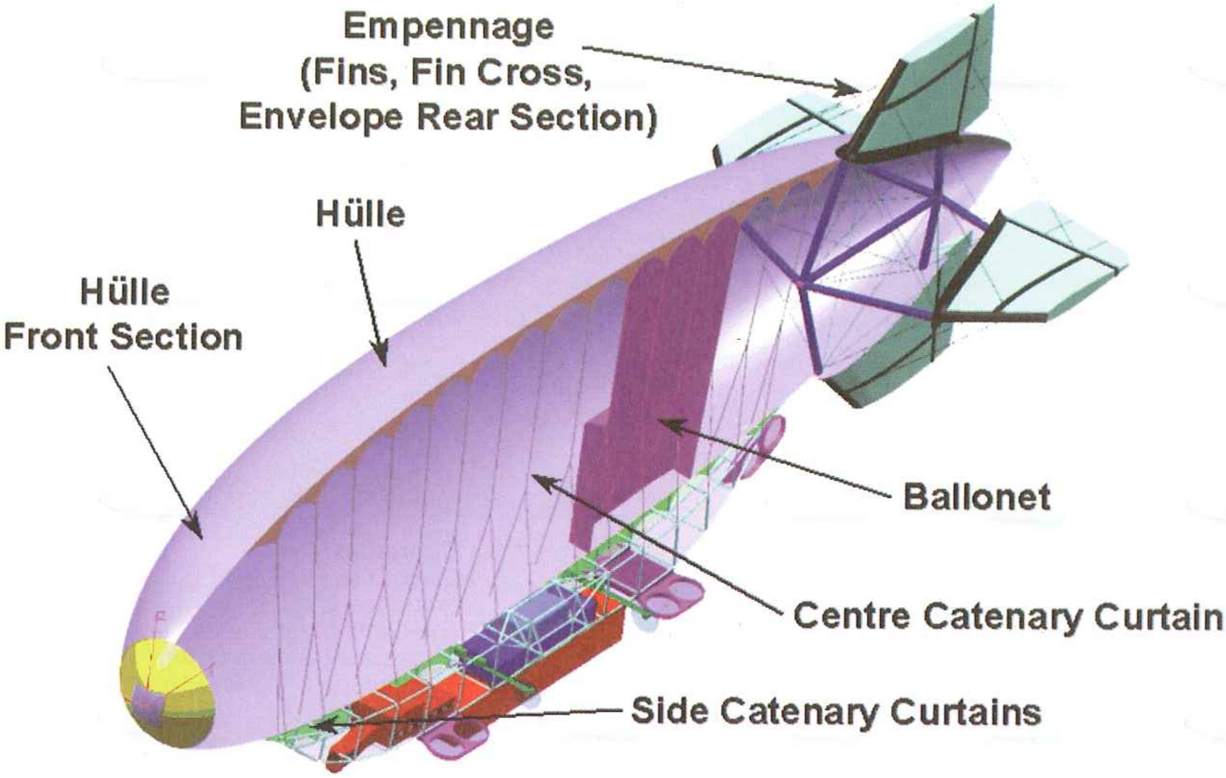

Figure 2: Cross-section of an Airship

for example, a volume of 550 000 cubic meters, which means a length of about 250m and a diameter of 60m. This compares to the great cathedrals of the world. The skin has the size of about 5 soccer fields and one stabilizer the area of about 600 m^2, which is larger than most backyards in southern Germany. Because of the bulky shape the drag allows only speeds of around 100 km/h.

Design Challenges

Overall the goal for a flight vehicle is a safe and reliable operation. The airship is a huge, extremely lightweight, inflated structure. The envelope consists of layered fibre composites of high strength and durability of minimum 20 years. The material and the seams of the body need a very low helium leakage. The forces of the load, the anchoring forces of the nose and the aerodynamic loads of the stabilizers, are made from aluminum or carbon fibre structures and transferred to the envelope by means of a flexible framework or cable structure. In case of CargoLifter, the flexible keel structure underneath the envelope is a carbon fibre space frame with a cross section of 10 by 10 m and a length of 150 m. The keel distributes the 160 tons point load and is itself connected to the structure by a so called catenary curtain, a harp like bunch of cables, which carries the loads up to the top centre line of the ship *[fig. 2]*. The keel also carries the crew compartment and the propulsion units. Propulsion and manoeuvring is achieved by 10 engines and various propellers. Four pressure control ballonets with a volume of about 30% of the total gas volume are inside of the body. The ballonets adapt the pressure of the gas of 400 Pascal to the various temperature and flight altitudes.

The key idea for CargoLifter is the load exchange procedure. The load is exchanged while the airship hovers 100 m above the ground like a flying crane. First the ship is mounted to the ground by central ropes. The ropes are pre-stressed by about 40 tons of additional lift. Along the pre-stressed ropes, the cargo slides to the ground and is exchanged against water ballast before the airship takes off again. This procedure gives the CargoLifter extreme flexibility and independence of ground infrastructure.

All phases of the operations, the functionalities and the systems, are modelled extensively by computer simulation and tests. The company has built up a full data and communication infrastructure as well as computer simulation tools *[fig.1]*, including an flight simulator. Detailed CAD, FEM and CAM models are developed for the preparation of manufacturing.

"... This compares to the great cathedrals of the world. The skin has the size of about 5 soccer fields and one stabilizer the area of about 600 m^2, which is larger than most backyards in southern German."

Figure 3: Airship Hanger

Beside the Airship itself, one of the big challenges is the airship dock. The biggest wide spanned hangar *[fig.3]* of the world is being built on a site 60 km south of Berlin and will be finished in 2000. The hangar is 350 m long 200 m wide and has a height of 108 m. Huge sliding doors open at both ends in order to avoid turbulence as far as possible when the airship is taken out. Also the manufacturing problems are challenging. The airship needs about 20% of the world helium production when it is filled. The nose cone has a weight of 20 tons and has to be mounted 50m above the ground. 20 000m seams have to be manufactured with 3m/s and automatically inspected. .....

Operation

CargoLifter is already building load exchange centres all over the world. The company has also been developing a special solution for cargo handling and transport and is far from being just an airship company. It has braved the challenge, to promote a new transport system, and introduce it into the world. It will change the heavy lifting business – and it will change our mind towards future technology.

Figure 4: Cargolifter

CSMA
The French Computational Structural Mechanics Association

by
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LMT/ENS de Cachan
and Roger Ohayon
CNAM Paris

In France, modern mechanics of solids and structures started out late, beginning with the theoretical aspects. Structural analysis, somewhere between theoretical mechanics and numerical analysis, was still at a relatively low level of development in the 1980's.

The structural analysis community was actually born in 1985-1986 when the "GRECO-GIS Computational Structural Mechanics and Artificial Intelligence" was created. The latter was a network-type research structure around a rather general theme, linking academic and industrial teams. It enabled:

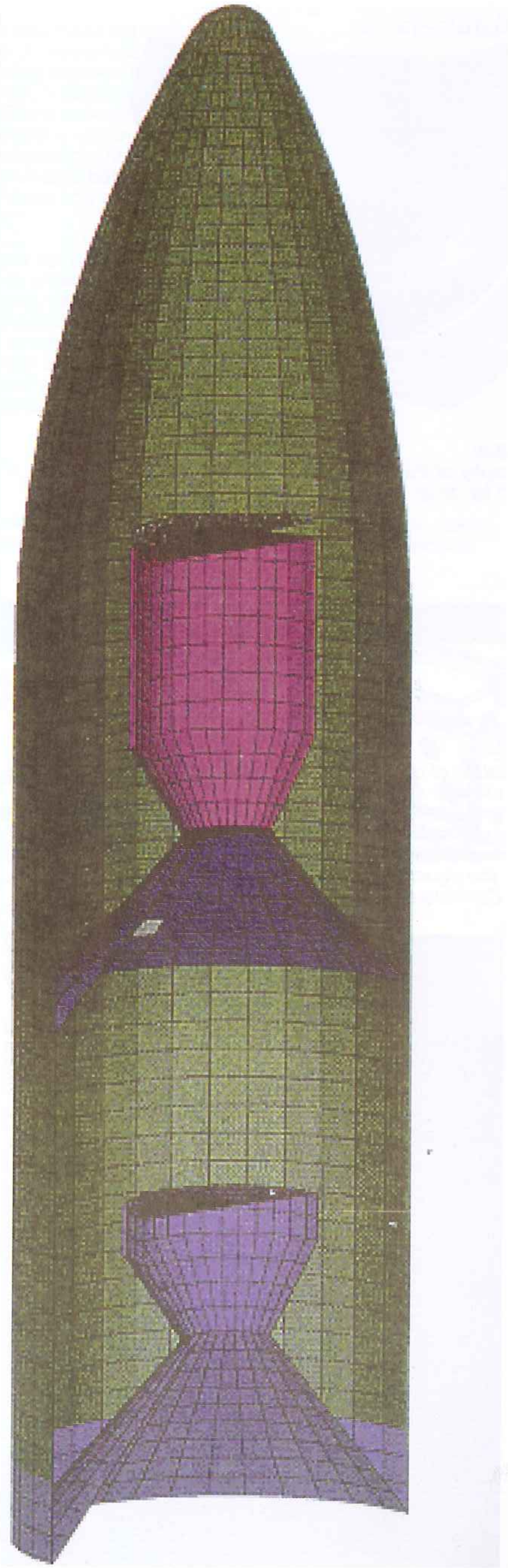
- the circulation of ideas within a community whose members had agreed to share results and associated benefits,
- the interaction of several specialties and cultures.

The heart of the research program, which reflected the needs of industry, aimed at broadening structural analysis to include technological considerations, performance improvement and the assessment of the quality of results, sound mechanics of materials and the most advanced programming techniques – particularly artificial intelligence. The GRECO part corresponded to the more upstream research, the GIS part to finalized research leading to the creation of application programs or program prototypes.

Created and led by Pierre Ladevèze, the GRECO-GIS was largely sponsored by the French National Research Council (CNRS), the Ministry of Higher Education and Research (MENRT) and the Direction of Military Equipment (DGA). This funding was used in particular to furnish a number of laboratories with workstations. J. M. Fouet and R. Ohayon were responsible of the two GISs. J.C. Lachat, J.P. Grellier, and R. Monin also played an important part in the success of the GRECO-GIS. The Scientific Committee was chaired by O.C. Zienkiewicz.

Figure 1:
View of the French Riviera at Giens where the French National Congress of Computational Structural Mechanics is held every other year.

Figure 2:
Vibro-acoustic model of the Upper part of Ariane 5 (2nd flight) (French National Agency for Space Studies - CNES, Evry)



It is interesting to note that other French mechanics communities were formed in the 1980's through the GRECO "Finite Strains and Damage" and the GRECO "Computational Fluid Mechanics".

At the beginning in 1986, the GRECO-GIS consisted of around 12 academic teams (75 researchers) and 15 industrial teams; in 1990, when it ended, it had 21 academic teams (100 researchers) and 31 industrial teams. Out of the forty-five program prototypes developed, fifteen reached the industrialization stage.

The GRECO was concluded by a "European Conference on New Advances in Computational Structural Mechanics", chaired by P. Ladevèze and O.C. Zienkiewicz, under the auspices of the IACM.

The community brought together by the GRECO-GIS decided to carry on the close cooperation among academic and industrial teams in the computational mechanics field and in 1990 created the Computational Structural Mechanics Association, affiliated with the IACM. Every other year, in particular, the CSMA organizes a National Colloquium on Structural Analysis in Giens, on the French Riviera *(Fig 1.)*.

This colloquium enjoys a growing success, as shown by the number of participants, in excess of 200, at the last colloquium organized by the LMA of Marseilles. Judging by the recent colloquia and the contributors involved, today's French computational mechanics community can be estimated at around 800 to 1,000 members.

The different boards of CSMA, chaired successively by R. Ohayon (90-96), N.Q. Son (96-99) and Olivier Allix, were attentive to the scientific quality of the colloquia, and also to the scientific liveliness of the field through the organization of one-day workshops. The subjects addressed are extremely varied: for example, the latest sessions were devoted to:

- alternative techniques to F.E.
- sensitivity analysis for nonlinear problems
- model adjustment
- boundary elements.

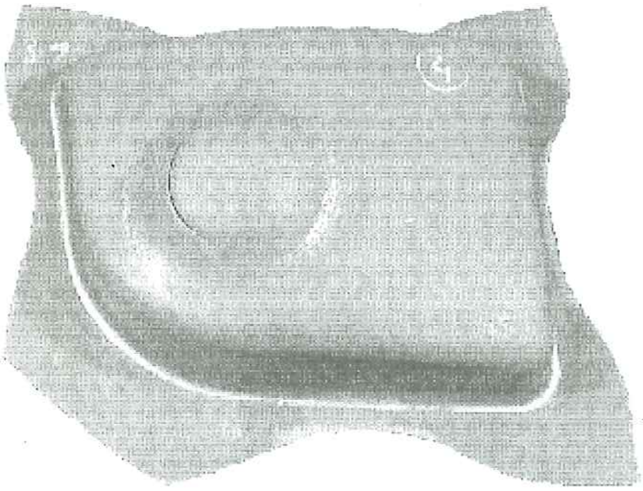


Figure 3.a:
Photography of the dashpot cup obtained by deep drawing

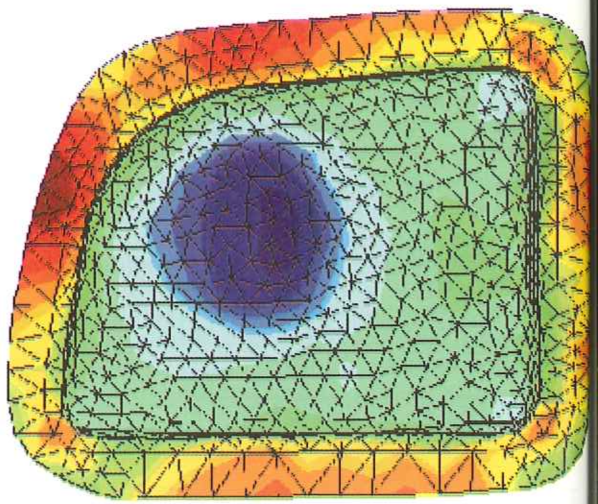
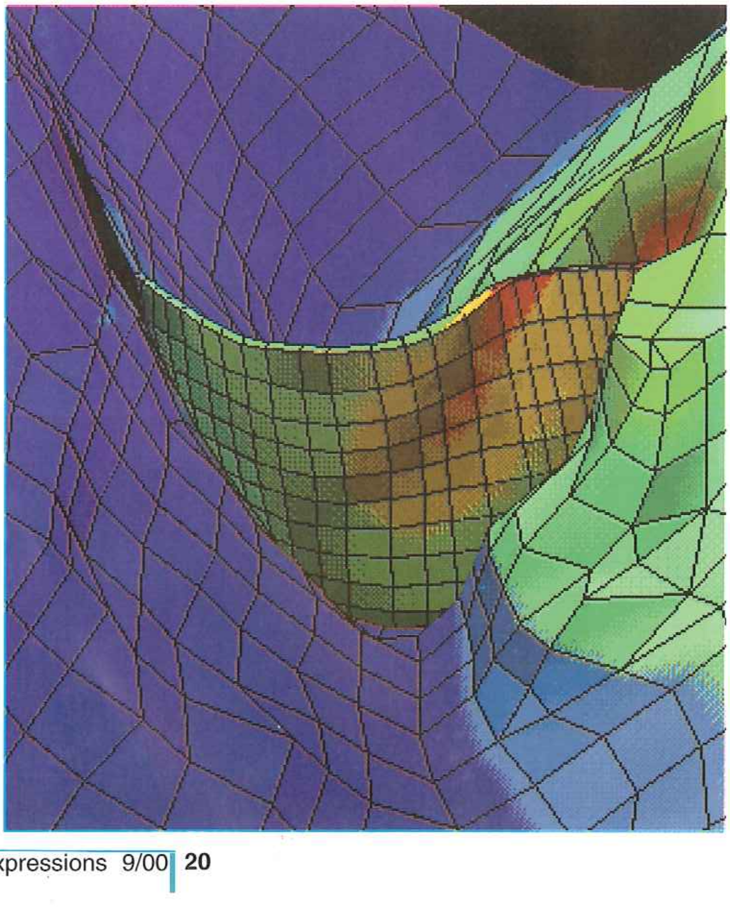


Figure 3.b:
Thickness distribution (mm) and contour of the optimum design (results obtained using Simplified Inverse Approach development at Compiègne University of Technology)

Figure 4:
Deformation of dam under an incident P wave striking the right bank with an incident angle of 45°. The influence of the reservoir together with the deformation of the bedrock and the site effect are accounted for in coupling FEM for the Dam and BEM for the fluid and the soil topography around the structure.
(Ecole Centrale de Paris)



The last colloquium in Giens (chaired by M. Raous and B. Cochelin) brought together 213 attendees, and 133 presentations were selected out of 169 abstracts submitted.

Traditionally, four speakers – two from the industrial world and two from the academic world – present a general conference.

In the last Giens meeting these speakers were O. Debordes (LMA-Marseilles) on "Structural Analysis and Software Architecture", J.C. Lachat (Usinor-La Défense) on "Research and Development in Steel Transformation", J.J. Moreau (LMGC- Montpellier) on "Evolution in the Presence of Unilateral Constraints" and M. Vialle (Eurocopter-Marignane) on "CAD, Analysis and Testing in Helicopters."

The main subjects treated were:

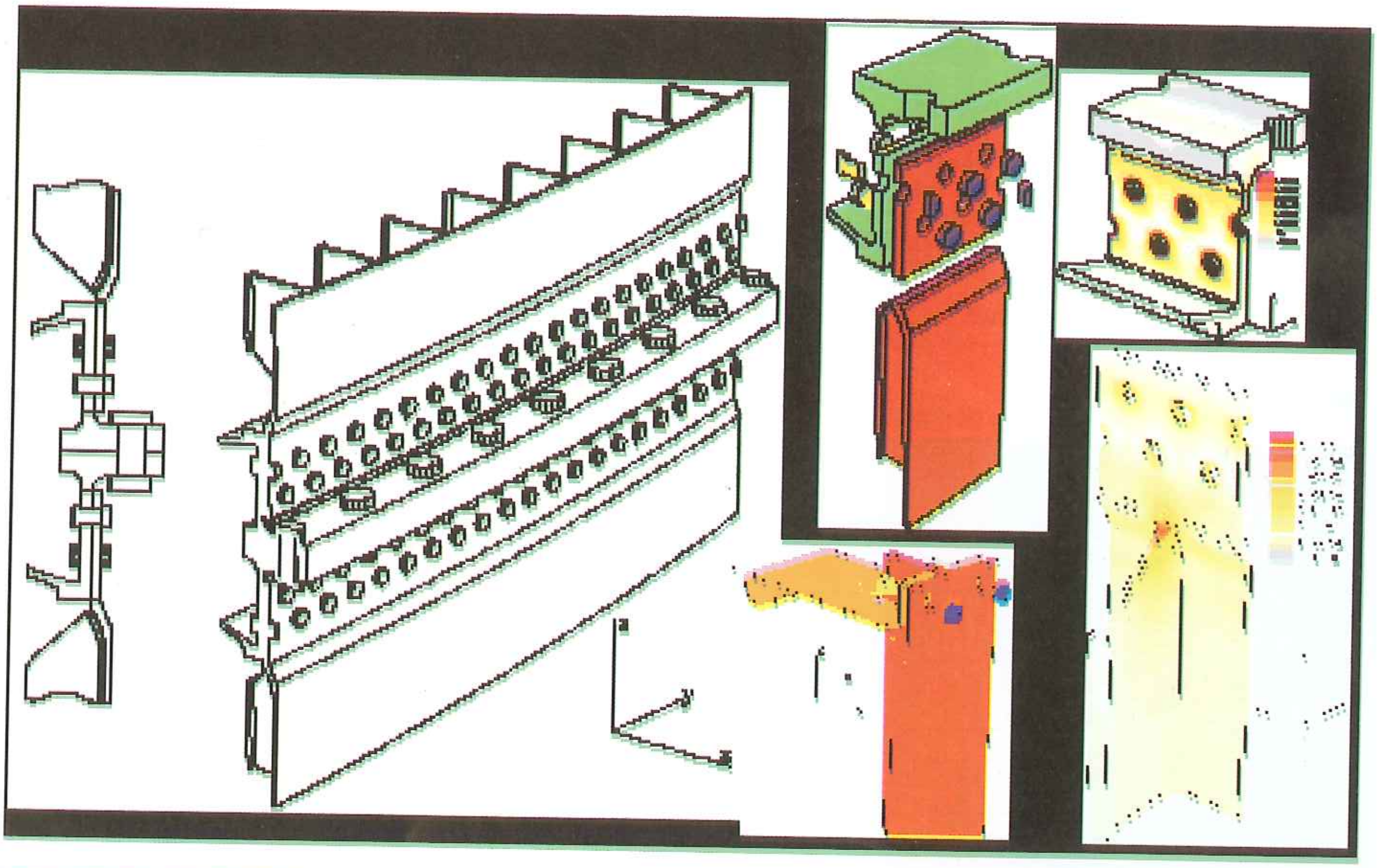
Dynamics, vibrations and active control	24
Constitutive equations, identification, composites	30
Numerical methods and alternative computing, software	20
Optimization, parallelism, meshing and adaptivity	20
Beams, plates and shells	15
Contact and friction	13

One should also point out that, in addition to the oral presentations, there is a special evening devoted to demonstrations of research software. All of this makes the Giens colloquium an absolutely exciting experience, with a mixture of engineers and researchers, and a very pleasant balance of beginning researchers and senior, established ones.

Besides these activities, the CSMA association is an acting scientific and technical group within the "French Mechanics Association" which is an association which brings together different scientific and academic organizations as well as a large number of industrial companies. ●

" ... an absolutely exciting experience, with a mixture of engineers and researchers, and a very pleasant balance of beginning researchers and senior, established ones. "

Figure 5:
Analysis of a 3D flange assembly (Distribution of the Mises stress) with a sub-structuring technique, taking into account friction and contact. A domain-decomposition type algorithm, suited to parallel architecture computers, is used as a solution procedure.



If you were lucky enough to have lived in Paris as a young man, then wherever you go for the rest of your life, it stays with you, for Paris is a movable feast.
Ernest Hemingway

A man is not idle because he is absorbed in thought. There is a visible labour and there is an invisible labour.
Victor Hugo

It has taken me all of my life to understand that it is not necessary to understand everything.
René Coty

Discretizing Ancient Pagodas in Thailand

by
Worsak Kanok-Nukulchai
Asian Institute of Technology, Thailand

Introduction

A pagoda is a monumental structure built in memory of Lord Buddha. It derives from the stupa of ancient India usually erected over the remains or relics of a holy man or king. This pagoda form of stupa, also known as Chedi in Thailand, was adopted by Buddhism as a monument enshrining sacred relics, and normally has little usable interior space.

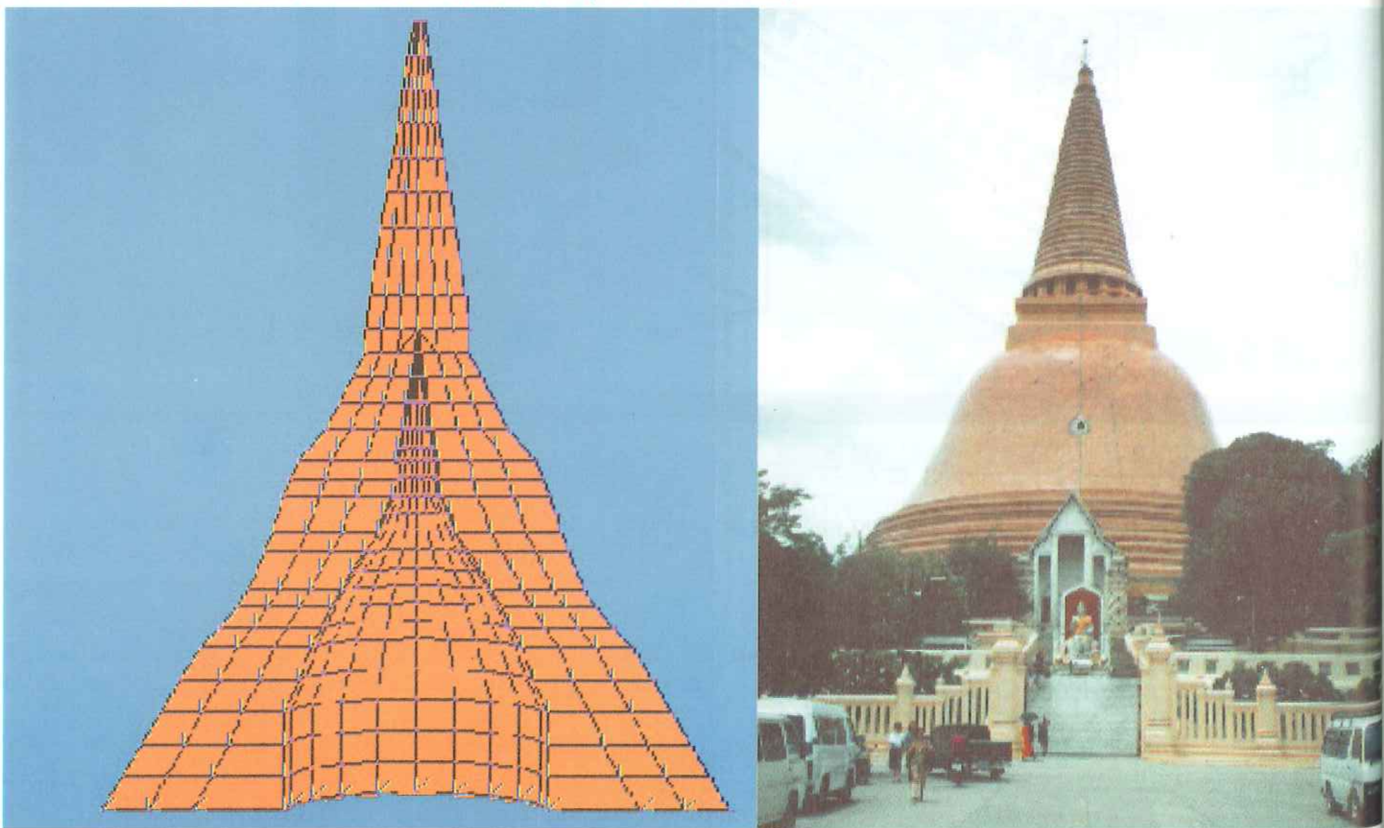
Thailand is well known for its rich culture and historical pagodas. Preservation of these ancient structures is of paramount importance. With the availability of numerical tools, such as the finite element methods, configuration of a pagoda can be modelled precisely to examine stress distribution under dead load, wind load and possible ground excitations. In general, for this class of ancient masonry structures, the sensitive areas are locations where tensile stresses are induced.

Pagoda Structure

Pagodas are relatively large and tall masonry structures that may or may not be hollow. They were constructed primarily from ancient bricks using lime mortar made from a mixture of lime with natural ingredients such as animal skins and molasses. While traditional lime mortar has an advantage in its low density thus allowing breathing of humidity and heat, its bonding effectiveness deteriorates over a shorter period of time.

Due to the above limitations, the masonry structure of a pagoda has been proportioned in such a way that its dead weight is basically carried by compressive stresses. These structures will last longer if significant tensile stresses are not developed at any location. However, over several hundreds of years, cracks and holes are visible in these structures, caused by the decays of structural integrity, uneven settlements of foundation due to subsidence and flooding, traffic vibrations, human intrusions, etc.

Figure 1:
Phra Pathom Chedi and its finite element model (half interior view).



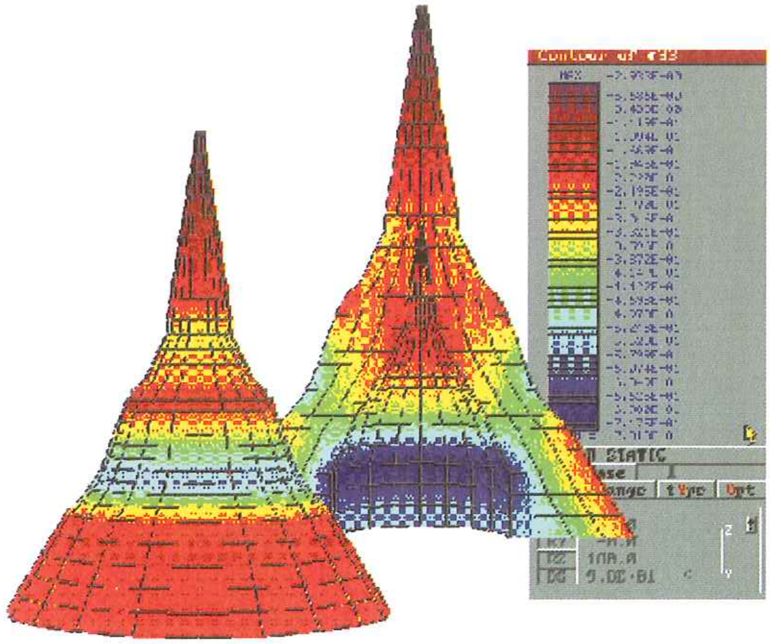


Figure 2:
Contour of vertical stress under dead weight

To construct an accurate finite element model, it is important to obtain precisely the physical information of the pagoda. The steps include
(a) on-site surveillance and measurement of the structural geometry;
(b) core sampling of constituent materials for laboratory tests of mechanical properties;
(c) geotechnical investigation to determine foundation parameters.

Based on the information, an accurate finite element model can be established for analysis to determine its responses to dead load, wind load, traffic and earthquake excitations. The envelope of stress contours will provide a hint on sensitive areas where cracks could form and propagate.

" Preservation of these ancient structures is of paramount importance."

Proper finite element modelling and analysis can help in the determination of stress intensities and distribution. This can be used to identify the sensitive areas where tensile stress or excessive compressive stress could have been induced.

Based on the results of such analysis, remedial or retrofitting measures can be designed to extend the service life of these important and precious national monuments.

Structural Behaviours

Structurally, a pagoda is a cone-shaped, dome-shaped or bell-shaped thick shell or solid. Because of the geometry, stress intensity due to its own dead weight concentrates around the centre. Under self-weight, although compressive stresses occur in most parts, tensile stresses may develop at some locations due to discontinuities, sharp changes in geometry and openings.

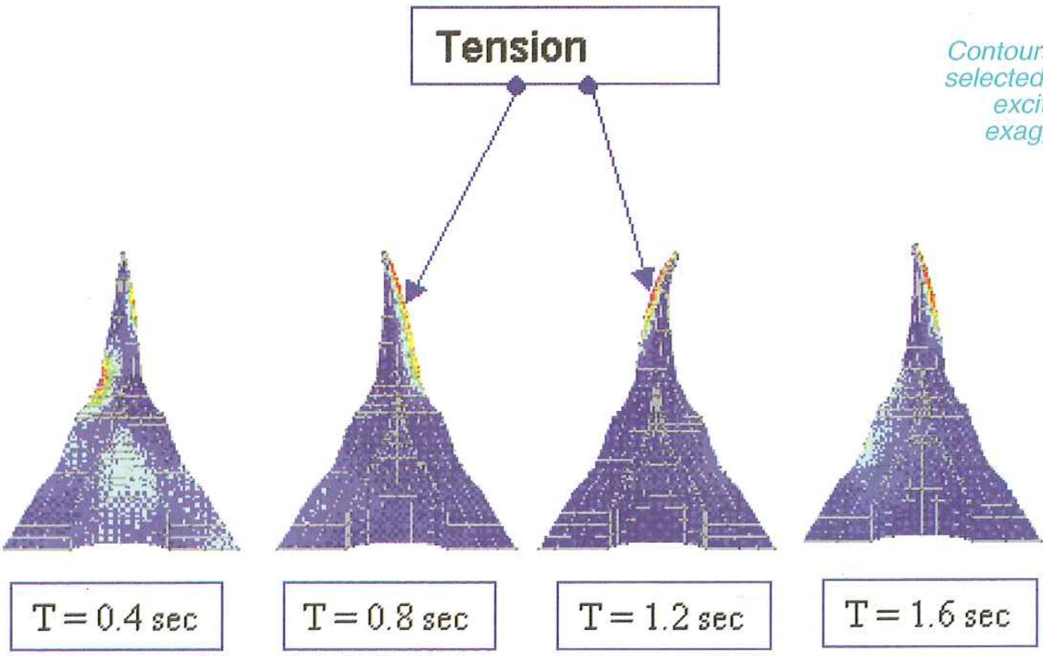


Figure 3:
Contours of principal stresses at selected time steps due to traffic excitation, with deformations exaggerated by 50,000 times

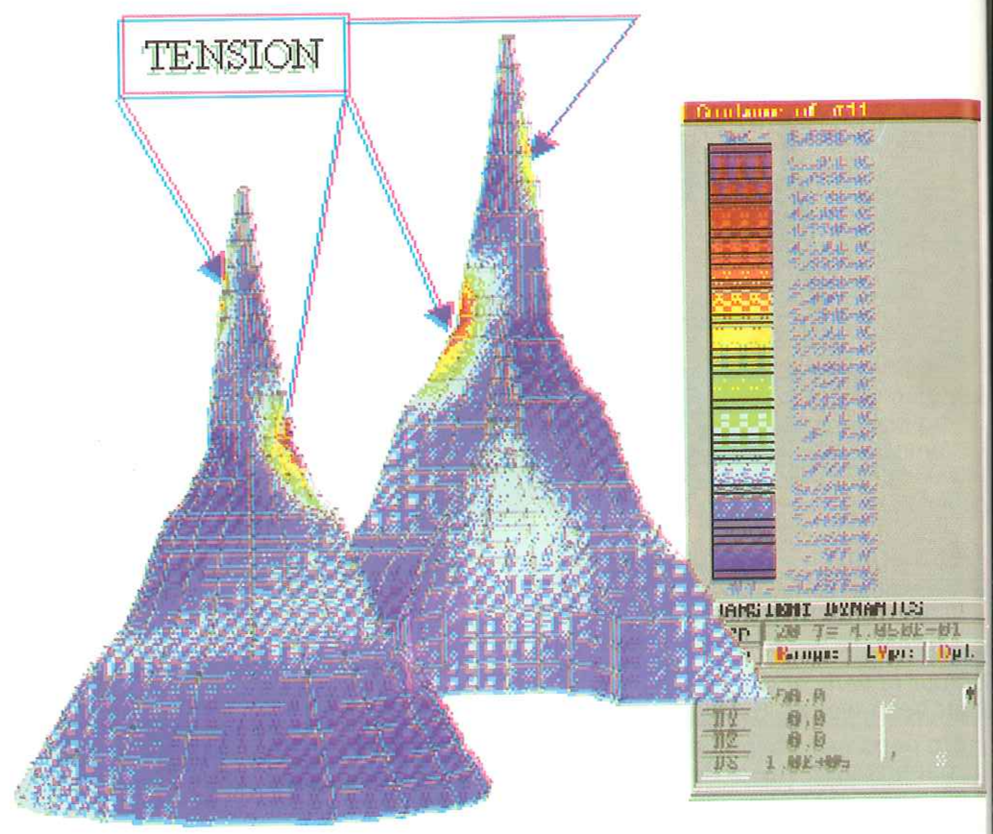


Figure 4: Contour of minor principal stresses due to traffic ground vibration

Tensile stresses may also develop in the pinnacle due to lateral loads and at the base due to uneven soil pressure distribution and settlement. Tensile stresses give rise to cracks in masonry and opening up of joints due to the aging ancient mortar. Cracks then gradually propagate and lead to a rapid deterioration. Distress may also be caused by a highly concentrated compressive stress that may either crush the masonry or split the bricks or open up the joints. It is therefore important to carry out a detailed finite element analysis of these structures to determine the stress patterns through out the structure.

" ... restoration of ancient structures can be processed more rigorously with respect and sensitivity to traditional materials and construction techniques "

Case Studies

Recently, out of concern over the deterioration of important ancient pagodas in Thailand, the Department of Arts has sponsored several studies to examine the current structural conditions of such structures using the finite element modelling. Results have been used to establish remedial measures. The following sections describe some of these projects.

Phra Pathom Chedi under Traffic Vibration

Phra Pathom Chedi, the oldest pagoda in Thailand, was built in the period of King Asoka the great in 308 BC. The pagoda, as shown in Figure 1, is shaped like an inverted basin and resembles the Sanchi pagoda in Asoka time. Its overall height and the base diameter are respectively 116 and 95 meters. This Chedi was left ruinously for years, until King Mongkut at the time of his priesthood, travelled on a pilgrimage to Nakorn Pathom province, and saw this giant pagoda standing in the jungle. He considered it as a sanctuary worthy of restoration. After his accession to the throne in 1852, he ordered his noblemen to restore the pagoda. Recently in 1993, when Department of Public Works proposed to build a new road approaching the Chedi, it was postulated that the vibration caused by the additional traffic could bring distress to the pagoda structure. The effect of traffic vibration on the stability of the Chedi was therefore studied, to find out measures for protecting this valuable ancient structure.

The process of study included:
a) assessment of traffic vibration due to heavy trucks in the form of measurement of particle velocity and acceleration along the base of the Chedi, and
b) developing a finite element model of the Chedi for dynamic analysis.

The inspection into the interior of the Chedi indicated that most of the bricks are still in good condition but cracks were found at some locations due to the deterioration of the mortar. This caused ceramic tiles to fall off and weeds to grow around these cracks. The brick and mortar samples were collected separately for laboratory tests.

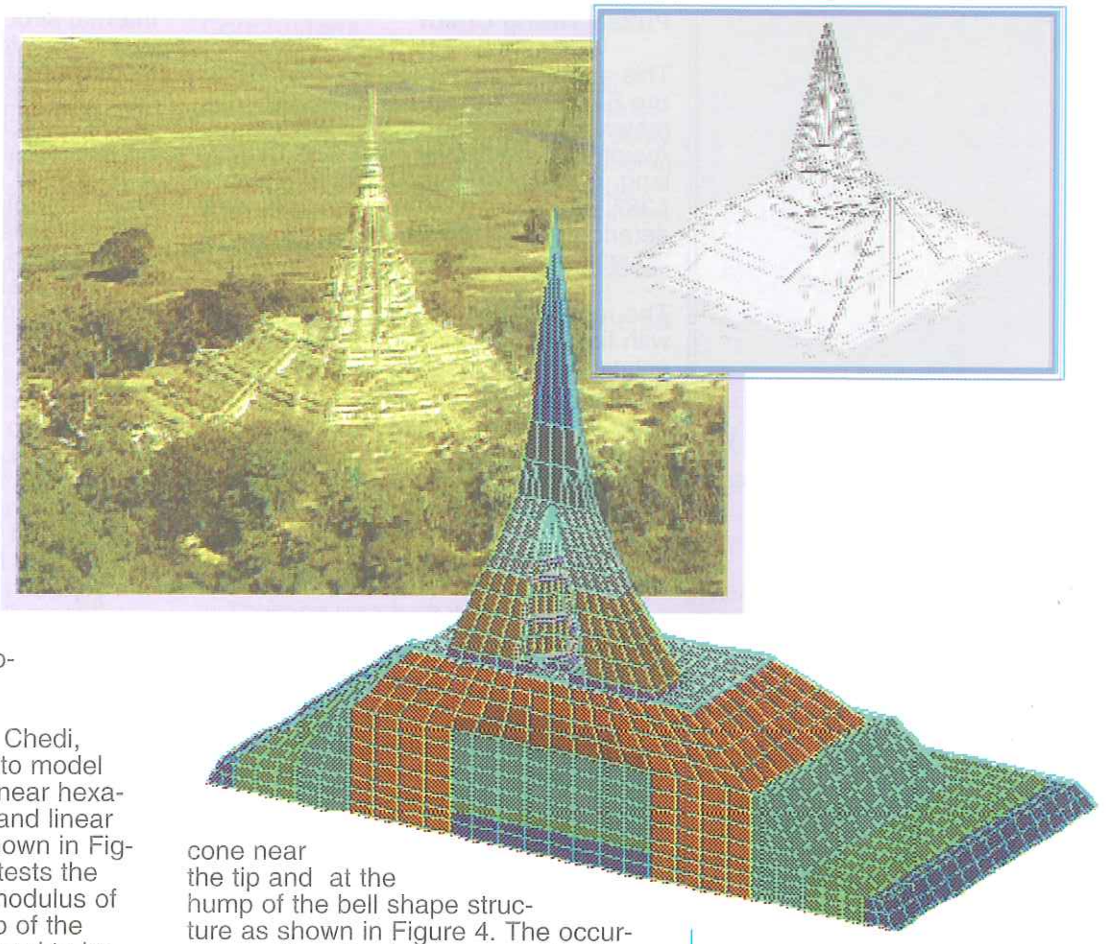


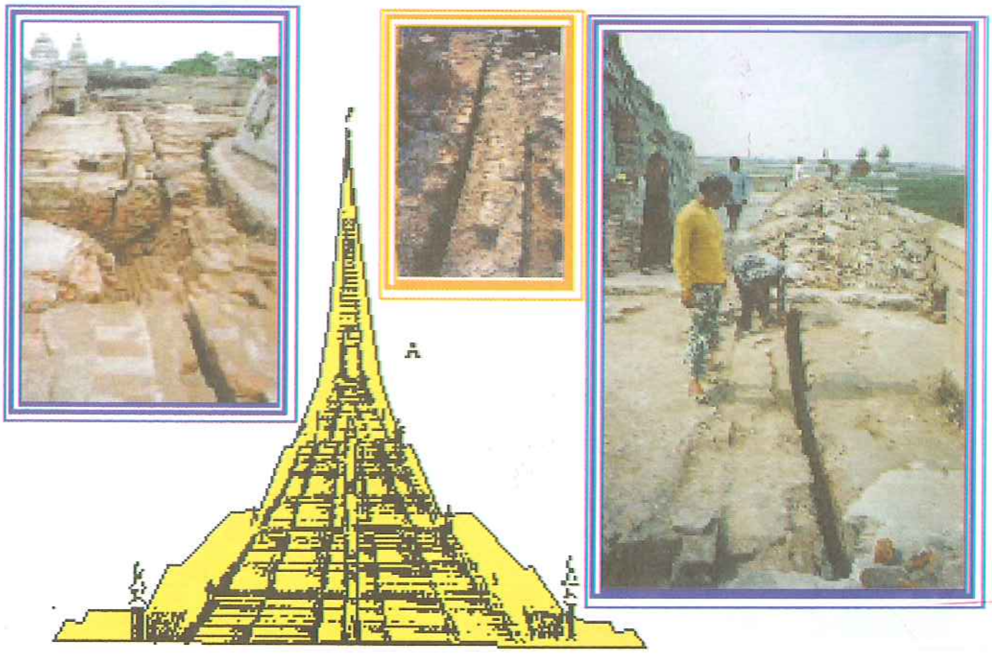
Figure 5:. Phukao Thong Chedi and its finite element model with grouted zone shown in red colour.

Due to the symmetry of the Chedi, it was considered sufficient to model half of the Chedi with 930 linear hexahedron, linear tetrahedron, and linear wedge solid elements as shown in Figure 1. Based on laboratory tests the compressive strength, the modulus of elasticity and Poisson's ratio of the masonry composite were found to be 28.21 kg/cm2, 28,210 kg/cm2, and 0.216, respectively and the average density of masonry was 1,760 kg/cm3.

Self-weight analysis
Under its own dead weight, the contour of stress is given in Figure 2. The maximum compressive stress is found to be about one-third of the ultimate compressive strength of the masonry unit. It can be said, therefore, that the present structure has a safety factor around 3 under its own dead weight.

Dynamic analysis
The structural model was subjected to ground acceleration induced by heavy traffic recorded earlier. The dynamic analysis was performed by Newmark's Time Integration Method using 2,000 time steps. The results provided a series of deformed states of the Chedi at time stations of uniform interval as shown in Figure 3. The envelop of stresses at these states enabled the peak stresses in the Chedi to be determined as an upper-bound effect of the traffic vibrations. It was found that this effect did not increases the magnitude of existing compressive stress significantly. However, it is observed that additional tensile stresses are induced by traffic vibration at 2 locations, i.e., at the inverted cone near the tip and at the hump of the bell shape structure as shown in Figure 4. The occurrence of tensile stress is undesirable, as opening can be initiated due to the aging of lime mortar. Cracks can then propagate, leading gradually to the overall deterioration of the structure. As a matter of fact, cracks have been observed at the same locations as predicted by the results.

Figure 6: *Proofs of ancient rehabilitations that involved layers of brick walls to enbrace the tilting structure. The line sketch of the original Phukao Thong appeared in a book authored by a German doctor, Engelbert Kaempfer, who visited Siam in 1690.*

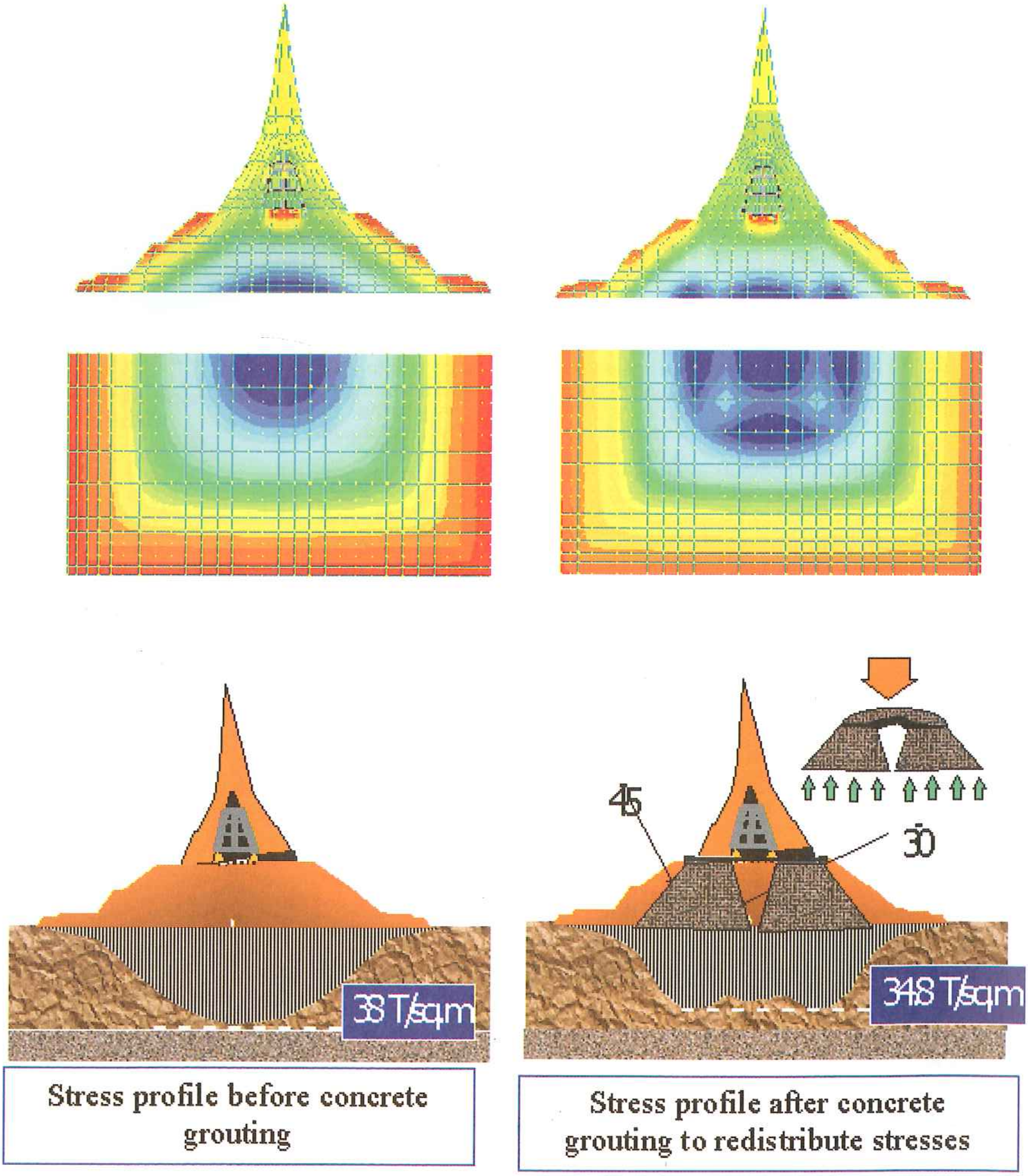


Pukao Thong Chedi

This ancient pagoda as shown in *Figure 5* is 64 meters in height and 75 meters in base diameter. Located in Ayudhaya, the former capital of Thailand, it was built by King Ramesual in 1387, and over the 600 years span has deteriorated badly with the tip tilting at 2.1 meters off-centre.

The rehabilitation program starts with field surveillance, followed by geotechnical investigation. To establish its internal structure, undisturbed samples were extracted by coring for visual inspection, and then tested in the laboratory to obtain its mechanical properties. The result of field investigations revealed that the tilting of this pagoda was caused mainly by internal collapses most likely not long after the pagoda was built. Many patch works were added along the course of many hundreds of years by various kings of Ayudhaya, in attempts to embrace the original structure from further tilting.

***Figure 7**: Stress redistribution over a wider base after concrete grouting was installed.*



Finite Element Model

A comprehensive finite element model is set up to analyse stress distribution in the pagoda under its own dead weight of 1,813 kg./cu.m. Considering an axis of symmetry in the tilting direction, 3,294 linear hexahedron, linear tetrahedron, and linear wedge solid elements with a total of 4,157 nodes were employed to model half of Pukao Thong Chedi as shown in *Figure 5*. While results of the analysis show small tensile stresses at locations around the surface, compressive stress mainly concentrates near the centre of the base. The maximum value of compressive stress is found to be 3.8 kg/sq.cm, a value much less than both the compressive strength of masonry and the bearing capacity of the soil foundation. Under this ideal situation, it is unlikely that the pagoda could collapse by distress. However, this finite element analysis assumes that the pagoda body is full, like a perfect continuum with no interior defects such as holes and cracks. In reality, the inspection based on cored samples showed patterns of cavities *(Figure 6)* that revealed at least two historic attempts to control the tilting of this pagoda by building layers of brick walls to embrace the original structure. In addition, some holes were discovered in the base possibly due to human intrusions for valuables.

Rehabilitation

The step for rehabilitation was to inject grouting concrete to fill in the cavities and holes. The grouted zone was controlled to form a shape of an inverted bowl as coloured in red in the model shown in Figure 5 so that stress can be redistributed away from the centre as shown in Figure 7.
Cracks around the surface due to tension were then sewed using rock bolts. Finally, the Pukao Thong Chedi was replastered with special ancient lime that allows breathing of humidity and heat to prolong the erosion of bricks. The final photos of the pagoda before and after rehabilitation are shown in *Figure 8*.

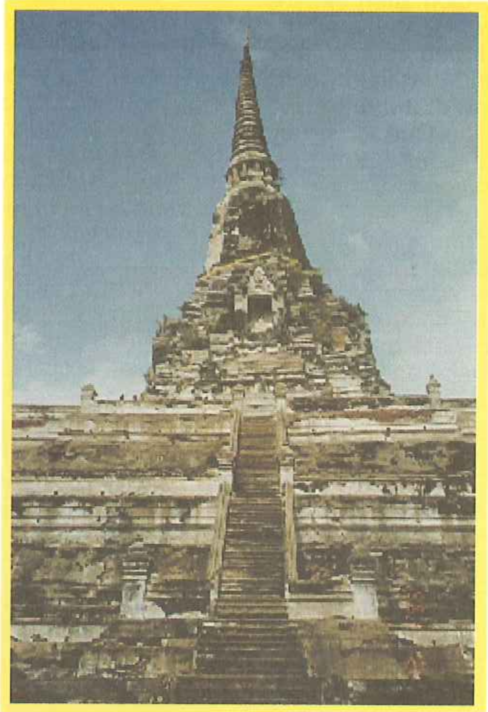
Conclusions

With modern tools in computational mechanics, restoration of ancient structures can be processed more rigorously with respect and sensitivity to traditional materials and construction techniques. With results of stress contours obtained for comprehensive finite element model of pagodas, it can be concluded that cone-shaped, bell-shaped and dome-shaped pagodas have weathered the test of time because stresses induced by its own dead weight are mostly compressive. The time selection of pagoda shapes is very much an act of Darwin's survival of the fittest, although it was often attributed to the wealth of indigenous intelligence to honour our forefathers.

Phra Pathom Chedi, the oldest pagoda in Thailand was built in the period of King Asoka the great (about B.E. 235).

The study reveals that the traffic vibrations on the proposed new road may not affect the stability of Phra Pathom Chedi structure in a scale as to cause sudden collapse. Nevertheless, as cracks can be initiated and propagated, they can gradually lead to the overall deterioration of the structure. ●

"...it was often attributed to the wealth of indigenous intelligence to honour our forefathers."



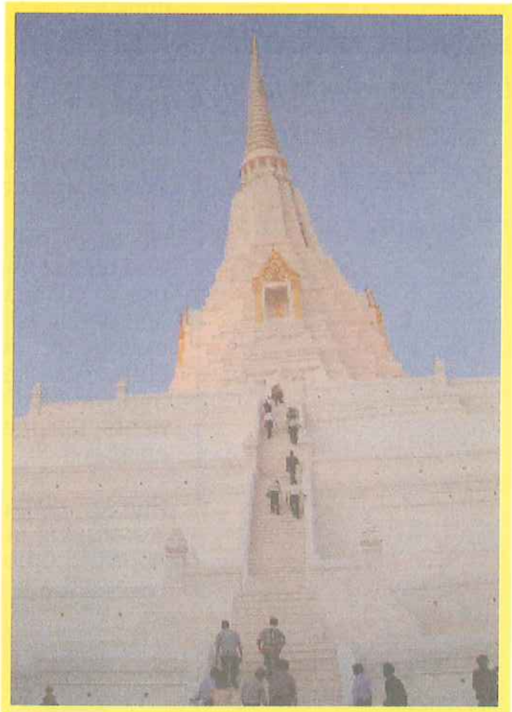


Figure 8:
Phukao Thong Chedi before (1997) and after (1999) rehabilation

The Finite Element Method

Why the Fifth Edition?

by
O.C. Zienkiewicz
& R.L. Taylor
Barcelona
Spain

" It seemed clear that here was a method that was practically important and which was so well suited to the computer which had been born by then that its future expansion was to be unlimited. "

Our colleagues have been asking why, after so many years of existence and success, this book is again going to appear in a new guise. Well, we shall describe, seriously we are afraid, the reasons and our motivation without using jocularity. Of course we are serious! Of course it is very important! And of course we must not neglect the invitation by EXPRESSIONS to "crow" about our efforts to launch this book at ECOMAS 2000 which is probably the biggest conference on finite element applications in this first year of the third millennium.

When the first edition of this book was planned and executed its objectives were to provide engineers and also mathematicians with an introduction to the new numerical procedure which was by then already named the Finite Element Method. The date of publication was 1967 and up to that date no comprehensive reference on the subject had appeared with all the information being scattered in a handful of papers.

The first author (OCZ) felt that a need existed for a book which would summarise the current position fully and outline the principles which governed the finite element approximation. At that time the subject was largely confined to solid mechanics, though some limited applications beyond that field were taken. It was found that a mere 272 pages sufficed at the time to present adequately the status of the method and its application fields.

However, the field was growing rapidly and already at that time the practical use of calculations was quite large. The first dams using the finite element method for design were being built and certainly in aerospace engineering many aircraft were flying with components designed by the use of such calculations.

Further, electro-magnetic calculations were being pursued by a very similar approach, though at that time not named the finite element method.

It seemed clear that here was a method that was practically important and which was so well suited to the computer which had been born by then that its future expansion was to be unlimited. This proved to be the case and in the following few years of the late 1960's a tremendous number of publications appeared, developing new approaches and discovering new possibilities. One of these was that of mapped isoparametric elements which came in the late 1960's and permitted quite complex elements to be used with mapped curved shapes. All this obviously required a further text and this was indeed produced in the second edition which appeared in 1971. This doubled the number of pages of the first and yet did not do justice to all the papers which by then had appeared. It is surprising that when this edition materialized there were still no other books dedicated to the subject.

When the first edition appeared its preface expressed the hope that perhaps in due course a mathematics of finite elements would be established and that the whole subject would become a more powerful one. These ambitions were certainly fulfiled. The mathematicians entered the arena in the 1970's and have unanimously declared it to have the strongest theoretical foundations of any other numerical approximation procedure. The fact that many engineers cannot follow the details of the very sophisticated proofs and analysis presented there does not diminish its value. However, for those familiar with the language of modern mathematics, such proofs are useful. But what perhaps we are striving to reach now is a unification of methodologies. It appears to the authors that at long last the finite element method provides the platform on which all the other methodologies, such as finite differences, boundary solutions, series solutions, etc., can be united under the same theory. And indeed this presents opportunities of utilizing the merits of any one of these procedures. All this will be presented in the forthcoming volumes in some detail.

Despite the fact that modern mathematics considers the finite element method as one in which it can establish its proofs and its procedures with precision, we have decided not to use modern mathematical language in our book. The reasons for this are clear. The book is intended for use by engineers and scientists to explain the reasons why and provide a clear insight into the many possibilities of application. This does not mean that any of the statements made in our book are incorrect or imprecise. In our view we believe they are all precise, but the proof of this in detail we leave to others. Thus, there is very little reason to introduce the shorthand of modern mathematics and make the book less readable by those who do not possess its details.

At the same time as the "rise" of mathematics was occurring, a close friendship developed between both of the authors and we attempted many joint research, which culminated in a very adequate solution of the original plate and shell problems. This work, and many other directions, led to publication of the third and fourth editions.

Each of these editions required a very much larger volume, rising to some 787 pages in the case of the third edition and 1455 pages for the fourth edition (which by then required two volumes). It became clear that it was impossible to present all the ranges of applications being made by industry and that great selectivity would have to be made in the future as to the subjects which were essential to new applications and methodology, and those which were so specialized that they only had application to particular cases considered.

Indeed, by the time the fourth edition appeared in 1989 and 1991 it appeared that the aim was achieved and that we had reached a stage in which the subject could only be augmented by edition of specialized texts. However, this was not to be. In our opinion, many fundamental developments, cutting across the subject boundaries, have been made since and it became obvious that these needed yet a further edition for their presentation.

This was the essential reason for starting the fifth edition work which originated from ideas for updating the fourth edition and culminated in a largely new reference now divided into three volumes without a significant increase in size.
In this new edition we chose the idea of a three-volume presentation to separate the topics of solid mechanics and fluid dynamics from those of the general finite element approach. This subdivision was, in our opinion, essential to provide the necessary background which could be used in new fields and also the particular procedures such as treatment of non-linearities in the subject of solid mechanics and the treatment of non-self adjoint terms in fluid mechanics. This would allow the methodology to be extended elsewhere and at the same time provide a background for those wishing to use the procedures in the specialized fields mentioned.

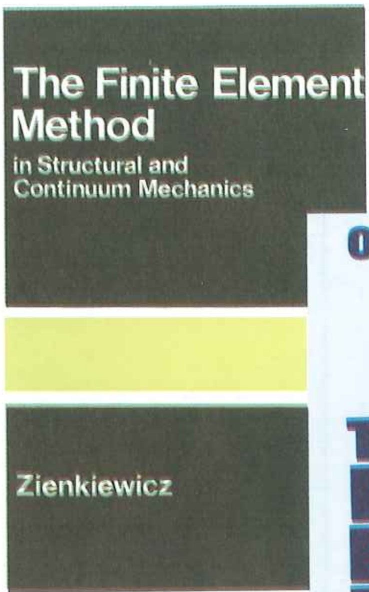
Clearly, in the future, other texts could appear, and indeed some already have, in dealing with topics such as optimization, biomechanics, electo-magnetics, heat transfer, and geomechanics. However, the reader will find the essential armoury for dealing with such problems is treated in the present volumes and that perhaps these specialities should not be included in detail in this general book.

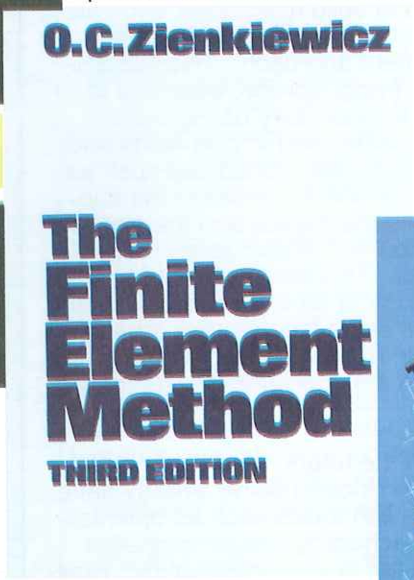
" The book is intended for use by engineers and scientists to explain the reasons why and provide a clear insight into the many possibilities of applications. "

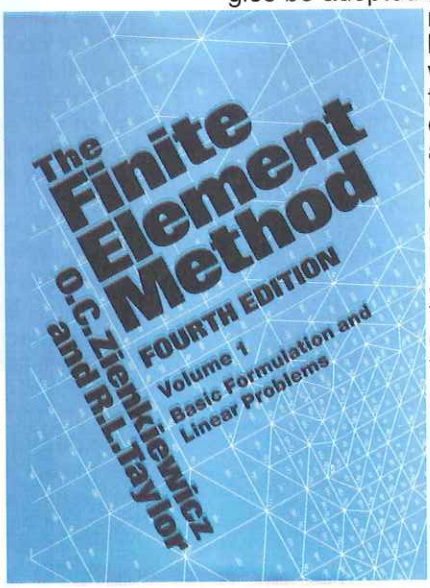
Olek and Bob enjoying the sun in Sitges, Spain

As mentioned before, the reason for the fifth edition was also the fact of rapidly developing general procedures capable of dealing with special problems. Here we must mention, as probably the most important, the subject of error estimation and adaptivity, This, throughout the 1990's, has been developed into a state, and having it feasibly inserted into commercial programs and achieving, by an automatic selection process, results of a given accuracy.

Another area in which much progress has been made is that of fluid dynamics. Here the early breakthroughs of dealing with high speed compressible flows, achieved in the mid 1980's, led to much consolidated by the development of new algorithms and procedures presented in the 1990's. These now allow us to present the whole range of fluid dynamics problems in a unified form.







Not only new subjects but also very old ones were much revitalized by reconsideration. Here we must mention the field of plate and shell problems which provided the first testing ground of finite element methods and which, in recent years, have been changed drastically. No longer is the thin plate and shell theory considered to be the starting point, but by a process of mixed formulation a direct degeneration of solid mechanics to these problems is available.

The 1990's have also seen much work laying the foundations for the developments which will doubtlessly expanded further in the 21st century. One of these areas is that of continuing but rapid expansion of computing power which allows very large size problems to be dealt with but introduces the difficulty of mesh generation of vast complexity. Many authors have addressed the problem of meshless methods, hoping computation procedures could be developed without the need of mesh generation. This work is much reflected in the new edition and here we introduce the reader to adaptive finite differences on irregular sets of "points" as well as to, so called, "meshless" Galerkin methods. These and other possibilities of future work are presented but the reader should perhaps note that computer hardware expansion, which is proceeding in recent years at a rate similar to that of early development of computer availability, is also very much affecting the methodologies being used.

" ... How will this new venture fare? ... We leave the matter in your hands. "

A colleague informs us that, in the very near future, a problem involving more than a billion unknowns is to be undertaken. Clearly, the methodologies for dealing with such problems must be, and indeed are, quite different from those which we postulated in the early editions of the book. For instance, in problems of this magnitude, only iterative solution procedures should be considered to solve the equations formed, with simple elimination not now being feasible. Does this, by necessity, require the elimination of complex elements or should such methodologies be adopted more widely. Again, the readers in future will have to consider it; all we can do now is lay the foundations of the procedures which will be available.

One way in which a text may be made to last longer periods than achieved in previous editions is to separate the computer software from the book and provide a continuously updated system through an internet web page. We have adopted this process by which our programs are made available to the reader on the publishers web pages. These pages, rather than "calcifying" into the error containing forms, will be maintained and further developed by the authors and their research students and colleagues.

In the preceding we have, quite seriously, outlined our aims and motivation for the work which we hope will be ready in print in early September. Have we achieved the objectives here outlined? How will this new venture fare? We leave the matter in your hands.

One last remark is the fact, as noted above, we have chosen not to provide the computer programs within the books. This not only saves space but allows us to update the developments continuously and of course allows easier translation and utilization methods.

Well here goes! ●

In Memory of

Prof. Ernest Hinton

Prof. Ernest (Ernie) Hinton died on 18th November 1999 after a long and valiant battle against illness which he fought with enormous courage and dignity.

Ernie developed his scientific career at the Civil Engineering Department of the University College of Swansea in Wales. There he become a leading figure in the international computational mechanics community. His work on finite elements related to structural analysis and optimisation in particular, will be remembered by future generations of students and researchers. Ernie was also actively involved as an editor of several international journals and was a member of several international committees on computational mechanics.

We had the unique opportunity of working hand in hand with Ernie in a number of projects and activities for the last 20 years. On December 1979 we jointly organised an introductory course to finite element methods at the School of Civil Engineering in Barcelona, Spain. In the course Ernie's lectures impressed the audience for their clarity, perception and interest. The course was extremely successful and it was repeated annually in same location for the subsequent 10 year period. It soon became a tradition for the three of us, to meet in Barcelona with some other colleagues from Barcelona and elsewhere, for the "Christmas FEM course". Indeed this course is to be remembered as the beginning of a firm and active collaboration between the finite element community in Barcelona and Swansea which has fruitfully continued over the years.

On April 1984 Prof. Cedric Taylor from Univ. College of Swansea, Ernie and ourselves organised the International Conference on Numerical Methods for Non Linear Problems. This successful event was followed by the first Inter-national Conference on Computational Plasticity (COMPLAS), held again in Barcelona in April 1987. Four additional COMPLAS conferences were successfully organised in Barcelona by Ernie and ourselves in the period 1987 - 1997. The five COMPLAS meetings have become benchmark events in the international structural mechanics community. The 6th COMPLAS conference, to be held again in Barcelona on 11 - 14 September 2000 presents a special dedication to Ernie as a founder of this conference series.

We mourn the passing of Ernie, but at the same time we rejoice in the life and achievements of a great man and great scholar. Expanding the many ties between Swansea and Barcelona, which Ernie helped to establish, is probably the best tribute we can offer to his memory.

Eugenio Oñate
Univ. Politecnica de Cataluña
Barcelona, Spain

Roger Owen
Univ. College of Swansea
Swansea, Wales, UK

USACM MEMBER NEWS

Professor Ted Belytschko received the Theodoore von Karman Gold Medal of the Engineering Mechanics Division of the American Society of Civil Engineers. This is their highest award and was given for his contributions to nonlinear finite element methods, particularly the development of explicit methods and one-point quadrature elements, which made crashworthiness analysis and simulation of highly nonlinear problems in engineering feasible. He is the second member of USACM to receive the award; Tinsley Oden received it in 1994. Ted also received the Mel Baron Medal of the Shock and Vibration Institute for contributions to structural dynamics.

Kent T. Danielson, R. Aziz Uras, Mark D. Adley, and Shaofan Li received the Atanasoff Best Paper Award for their paper "Large Scale Application of Some Modern CSM Methodologies by Parallel Computation" at the 5th NASA National Symposium on Large-Scale Analysis, Design, and Intelligent Synthesis Environments, Williamsburg, VA, October, 1999.

Professor J. Tinsley Oden will be receiving an honourary doctorate from the Faculte Polytechnique de Mons in Belgium. It will be bestowed on him in September 2000. Professor Oden is being recognized for his research and contributions to computational sciences and engineering over a career spanning 30 years. He is the Cockrell Family Regents' Chair in Engineering #2, Professor of Aerospace Engineering and Engineering Mechanics and Professor of Mathematics at The University of Texas at Austin as well as the Director of the Texas Institute for Computational and Applied Mathematics.

Professor Charbel Farhat
Interim Chair, Department of Aerospace Engineering Sciences
Director, Centre for Aerospace Structures University of Colorado at Boulder
has been inducted as
Fellow of the AIAA.

USACM Election Results

Professor Joseph Flaherty Amos Eaton from Rensselaer Polytechnic Institute has been elected to the position of Secretary of the USACM. His research interests are in scientific computation, automated framework development for partial differential equations, adaptive solution techniques including mesh refinement, mesh motion, order variation, parallel computations, a posteriori error estimation techniques and singularly perturbed systems.

Joop Nagtegaal, Kaspar Willam, Klaus-Jurgen Bathe and Michael Ortiz have been elected to the position of At-Large Member of the Executive Committee of the USACM. Starting from October 2000 they will be joining continuing Members-at-Large: **Charbel Farhat**, **Carlos Felippa** and **Robert Spilker**. At that time **Wing-Kam Liu** will become the seventh President of the USACM. **Tom Cruse** will serve as a Vice-president and **Jacob Fish** as a Treasurer.

Submitted by Jacob Fish, USACM Secretary

For all inclusions under USACM please contact:
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The First USACM Student Chapter is Formed at the University of Texas

Submitted by
Professor J. Tinsley Oden

On the initiative of a group of graduate students, the first Student Chapter of the USACM was created at the University of Texas at Austin. The student organizers obtained permission from the University to create an officially sanctioned student organization and to function within the university student organization structure.

Kumar Vemeganti First President of the Chapter

A set of By-laws was prepared by the organizers and a preproposal for student status of USACM members has been submitted to the USACM Executive Committee.

Twenty -four students attended the inaugural meeting of the Chapter. **Kumar Vemeganti** was elected as first president of the Chapter and **Albert Romkes** was elected as the first Vice president and acting Secretary -Treasurer. **Prof. J. T. Oden** was named as the Faculty Advisor.

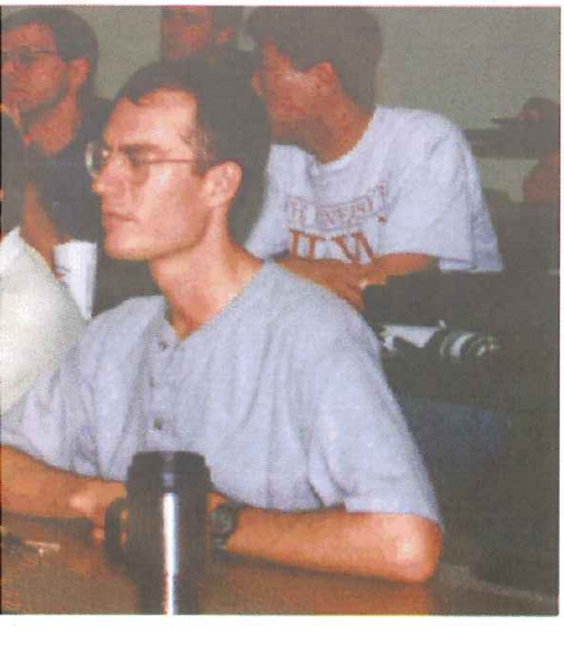
The first meeting, held on February 22, 2000, featured a talk by Oden on the history of the IACM and the USACM and a talk by Ivo Babuska on aspects of the history of Computational Mechanics and current trends.

The Chapter will meet regularly and manage it's own lecture and seminar series . A variety of activities of the Chapter were discussed and are being planned. A noteworthy aspect of the Chapter is it's interdisciplinary character: students from Aerospace Engineering, Civil Engineering, Engineering Mechanics, CAM (Computational and Applied Mathematics) , Computer Sciences, Physics , Mechanical Engineering, and Petroleum Engineering attended the first meeting.

Student Audience at the Inaugural Chapter

Prof. J.T. Oden
Faculty Advisor

Prof. I. Babuska



United States Association for Computational Mechanics ad hoc Committee on

Verification and Validation in Computational Solid Mechanics

Len Schwer
USACM Member-at-Large

Goal: The United States Association for Computational Mechanics (USACM) recognizes there is a need for assessing the credibility of computational solid mechanics simulations and has set as a goal the establishment of standards by which the credibility of computational solid mechanics simulations can be assessed.

On November 14 the Committee held it first meeting during the ASME Congress in Nashville Tennessee with fourteen members attending and formal presentations by seven members. Details of the meeting minutes and links to the presentations are available on the Committee's web site www.schwer.net/VnV.

The immediate objectives set at this meeting were to:

- Establish a team, led by Hans Mair (mairh@asme.org), to draft an outline of the V&V Guide that is the first goal of the Committee,
- Pursue becoming a Standards Committee under the ANSI approved standards procedures of either ASME or ASCE.
- Expand the membership to about 30 with a goal of providing the Committee with a diversity of view points.

Since that meeting the writing team has been formed and the draft outline is growing rapidly to confirm the scope of the task that has been undertaken. A draft document describing the organization and membership policies of the Committee has been created as the first step in preparing to become a Standards Committee. The membership has been expanded to 27 members with representation from industry, Government, national laboratories, and academia. A special effort was made to include expertise in experimental and probabilistic mechanics, as these are two areas often under represented in V&V efforts.

The Committee web site www.schwer.net/VnV attempts to document the activities of the Committee and communicate these activities to others interested in this V&V activity. Part of the web page is being developed as a resource page with links to documents and other web sites with relevant content. An email distribution list has been established for communication among the members, vnv@usacm.org but will also function as the means of communicating public comment to the Committee.

The next Committee meeting will either be in Chicago during the IUTAM Congress (Aug/Sep) or at the ASME IMECE in Orlando (Nov).

Expo 2000
Hannover

With Expo 2000, Hannover will become the first great meeting-point for mankind in the new millennium: the Niedersachsen state capital will welcome millions of visitors from all over the world. For five months, from **June 1 to October 31, 2000, Hannover** will be the centre of ideas and visions for the future – and the centre of a varied and ambitious culture and events programme.

Figure 1

A novelty of EXPO 2000 is that is theme, "Humankind – Nature – Technology", which is binding on all participants. The nations of the world's presentations will demonstrate their own ways of solving the issues of the future against the background of their specific social, cultural, economic and historical contexts.

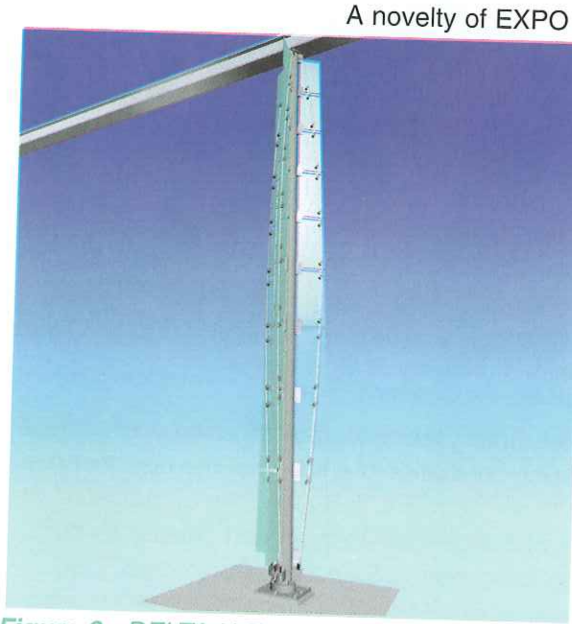


Figure 2 DELTA-X Engineering, Stuttgart

This is why, along with the culture-events programme and the thematic area, the world-wide projects are a major part of EXPO 2000.

Pavilions designed by leading architects invite you to embark on a world tour into the next millennium. In these, participants stage their presentations. Pavilions are either temporary buildings or erected for long-term use. The German pavilion *[Fig. 1]* with a ground area of around 12.000 square meters, is being built at the central Expo-Plaza. Its construction with the large glass front and composite pillars out of glass and steel was a major engineering challenge *[Fig. 2]*.

The Japanese pavilion embodies the main theme of Expo 2000 with its idea: "from design and construction to demolition and recycling". The Japan Pavilion is the first attempt in the history of world expositions to adopt the idea of using recycled paper as a construction material. This represents a major part of the construction, and hence is an interesting object from the engineering point of view *[Fig. 3 + 4]*. Here an optimum regarding safety against fire and material strength had to be achieved.

Figure 3

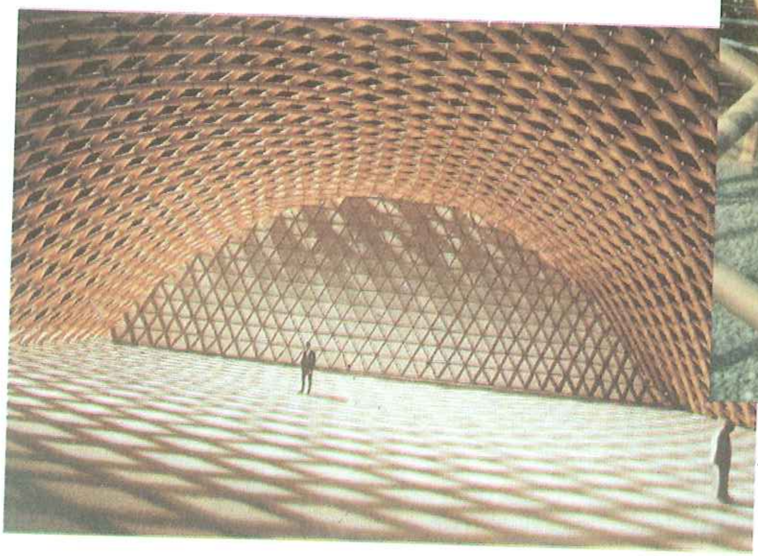


Figure 4

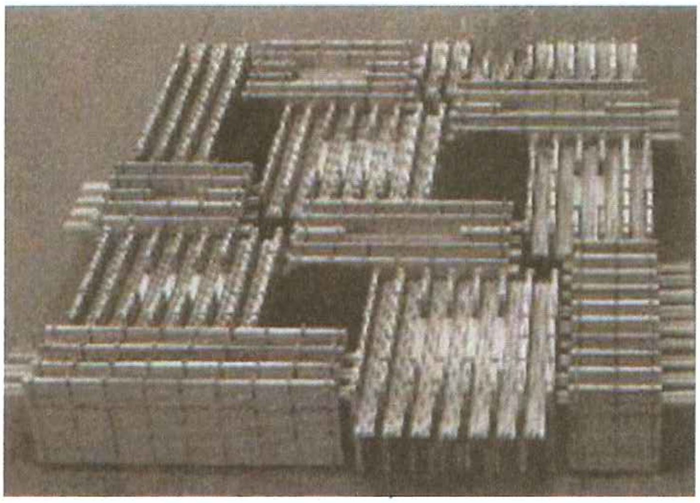


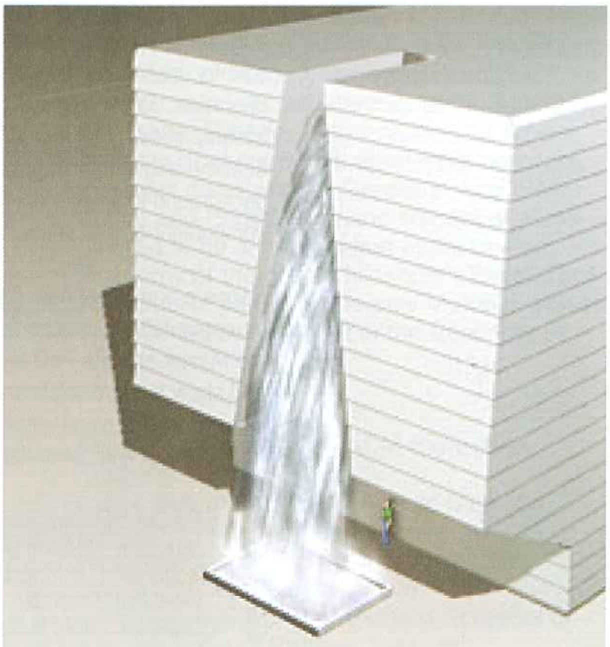
Figure 5

The EXPO's main theme can also be found in the construction of the Swiss pavilion *[Fig. 5]* designed by P. Zumthor. Its walls are made of beams of identical cut, piled up layer upon layer with dunnages in the gaps. The long wooden walls and the crossbeams are clamped together by mooring rods and steel springs, and fastened like heavy cargo onto the ground. As in a lumberyard, all beams are kept in perfect condition, ready to be dismantled after the exhibition and re-used as building timber.

Norway has build a pavilion with a thundering waterfall in one aluminium-clad structure *[Fig.6]*.

The Netherlands pavilion consists of six 'stacked' landscapes, as can be seen in [Fig. 7]. The building has no solid walls.

Figure 6



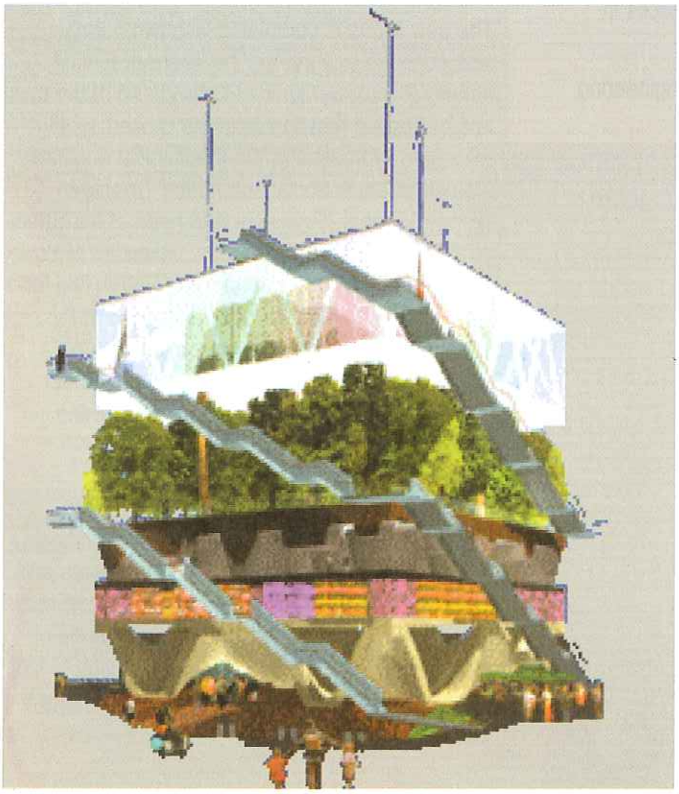


Figure 7

Onwards from the EXPO opening ceremony on 1st of June visitors will be captivated by the regular evening firework, light and laser show „Flambée“ in which actors, film makers, writers, musicians and producers are involved. A computer-controlled system directs and controls water fountains, geysers and 25-metre-high water-curtains which create three temporary screens each measuring 300 square meters in area for film and image projections.

Through music and dancing, special culinary campaigns, information and discussion events, each country will give an insight into its culture, way of life and history.

by
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University of Hannover

GACM NEWS

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http://www.gacm.de

International MSc & PhD Courses in Germany

English has been accepted worldwide as the modern „lingua franca"; and student migration has become a consequence of globalization. Studying abroad is not only an incentive, in many cases it is almost a requirement. Local language is a considerable obstacle, while English has become the first and major foreign language in high school in almost all countries. Learning an additional foreign language takes a lot of extra effort and time and has often prevented students coming to our country, making exchange programs a one-way operation. These general developments are accompanied by an increasing imbalance in demand and supply of graduates with a sound background in all different fields related to computational mechanics.

Hence a number of new graduate study programs on computational mechanics in Germany - both on the Master and the PhD level. All taught in English and show a interdisciplinary character involving lectures from several engineering departments, mathematics and computer science.

Some GACM affiliated graduate programs are:

- **come.tum** - MSc in Computational Mechanics (TU München)
  www.come.tum.de
- **COMMAS** - MSc in Computational Mechanics of Materials and Structures (Universität Stuttgart)
  www.msc.commas.uni-stuttgart.de
- **CSE** - MSc in Computational Sciences in Engineering (TU Braunschweig)
  www.tu-bs.de/cse
- ICCES - PhD in Computational Engineering Science (Universität Hannover)
  www.icces.uni-hannover.de

Further information on these programs can be found on the respective web pages or at http://www.gacm.de

Change in GACM Chair

At the end of 1999 Profs. Walter Wunderlich (München) and Erwin Stein (Hannover) stepped down from the Chairman and Vice-Chairman position of GACM where they served since its foundation in 1990. Their term was highlighted by the organisation of ECCM ´99. Both renowned scientists recently retired from their official University positions as well. Chairman Wunderlich has been strongly assisted by his associate Professor Gunter Kiener, the Secretary of the association. Two years ago Prof. Egon Krause, Aachen (CFD representative on the GACM board), also stepped down due to retirement.

At the last GACM assembly, during ECCM´99, Ekkehard Ramm and Peter Wriggers were elected Chairman and Vice-Chairman, beginning their term on 1 January 2000. Both scientists have been active in the national and international community of computational mechanics for many years. E. Ramm is Professor of structural engineering and head of the Institute of Structural Mechanics at the University of Stuttgart; Professor P. Wriggers recently moved from the Technical University of Darmstadt to the University of Hannover where he became the successor of E. Stein in the chair of structural mechanics and numerical mechanics. The team is strongly supported by the new secretary, Dr. Wolfgang A. Wall (Stuttgart) whose main research area, 'fluid-structure-interaction' fits perfectly into the objectives of the Association.

The new group is completed with two members who continue to serve on the board of GACM, namely Professor Günther Kuhn (head of the Institute of Applied Mechanics at the University of Erlangen) representing the mechanical engineering part of the Association and the Treasurer Werner Wagner (Professor and head of the Structural Mechanics Institute at the University of Karlsruhe). According to the rules of GACM, two further board members have to be elected at the next general assembly; these are supposed to be a representative of the CFD area and a member from industry. The procedure to complete the board is currently under way.

The GACM, as the national branch of IACM, strongly follows the objective of its international "umbrella" organisation, namely "to stimulate and promote education, research and practice in computational methods, to foster the interchange of ideas among the various fields contributing to this science and to provide forms and meetings for the dissemination of knowledge".

book report

Elements of Plasticity
Theory and Computation

I. Doltsinis (Ed.)
328 pp, 2000, US$ 183,
WIT Press, Southampton, U.K..
Providing the essential theoretical framework for understanding elastoplastic behaviour, finite element computational procedures and interpreting numerical results, this new text develops the subject of small strain elastoplasticity from classical theory to modern computational techniques.

The material on the theory of plasticity is derived from a course on elastoplastic structures taught by the author at the University of Stuttgart, while the sections dealing with computational finite element methods reflect his research and development work on this topic.

It is ideal for use by graduate and postgraduate students studying civil, mechanical, automotive and aerospace engineering. •

Thermodynamic Optimization of Finite-Time Process

R.S. Berry, V.A. Kazakov,
Z. Szwast & S. Sieniutycz (Eds.)
471 pp, 2000, UK Pounds 120,
Wiley, U.K..
This is the first book to provide a comprehensive treatment integrating finite-time thermodynamics and optimal control, and to give an overview of important breakthroughs in the field which have occurred during the last 20 years.

A survey of the optimization technique, including the basis of optimal control theory, and the principal thermodynamic concepts and equations are presented in the first four chapters.

The remaining chapters are then devoted to the solutions of a variety of finite time thermodynamic problems, and include coverage of their potential applications for the design and real technological processes.

Finally, special emphasis is placed on the consideration of cyclic processes and thermodynamic cycles, and their optimization and efficiencies. •

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ECCM`99 proceedings
Erratum

To order CD-ROM proceedings of the ECCM`99, payment should be done by bank transfer to:
GACM
account number 6 410 709 471,
HypoVereinsbank,München,
Germany, BLZ 700 202 70
or by bank draft sent to GACM.

In the advertisement appearing in IACM expressions No. 8 the account number as well as the bank code are not correct.

Word Puzzle

Answer from Page 11

The one thing that all eight words have in common is that each one contains three consecutive letters of the alphabet in a row.

In Memory of Professor Pericles Theocaris

On the 14th of September 1999, Prof. Pericles s. Theocaris passed away. He served the National Technical University of Athens as Professor (Ordinarius) of Mechanics, Rector of the University (twice) and Professor Emeritus, the National Academy of Athens as Secretary General and President and the Hellenic Society of Theoretical and Applied Mechanics as President for many years. He will be remembered for his pioneering work, which resulted in the astonishing production of more than 15 books and 900 papers, and especially in his efforts to promote Applied Mechanics research in Greek Universities

National Academy elects Prof. A. Kounadis

Prof. A.N. Kounadis of the National Technical University of Athens, Department of Civil Engineering, was elected Member of the Academy of Athens, Greece. The Academy of Athens consists of about 50 life appointed members, the most distinguished Greeks in Arts, Sciences and Engineering and somehow is considered to be a continuation of the ancient Academy of the great philosopher Plato. Prof. Kounadis is presently the only Member with an engineering background in the Academy of Athens.

New Members of the IACM Executive Council

Three new members have been recently elected to become members of the IACM Executive Council. These are Prof. Ted Belytschko from Northwestern University,U.S.A., Prof Bernard Schrefler of the University of Padova, Italy and Prof Somasundaram Vallippan of the University of New South Wales, Australia.

CSIM elects Secretary General

Prof. Bernard Schrefler from the University of Padova has been appointed the Secretary General of the prestigious International Centre for Mechanical Sciences of Udine, Italy.

Spanish and Portuguese Associations merge National Conferences

SEMNI (The Spanish Association for Numerical Methods in Engineering) and APMTAC (Portuguese Association of Theoretical, Applied and Computational Mechanics) have decided to merge their National Conferences which in the past were run separately. The decision was taken at the last APMTAC conference held in Aveiro (Portugal) from 17 - 19 April 2000, following previous meetings between officers from SEMNI and APMTAC. The first joint conference will be held in Madrid in April 2002. This will be followed by a similar event to take place in Lisbon in the year 2004. It is expected that the new united conferences will become a reference event in the Spanish and Portuguese speaking world as well as at a wider international level.

conference notices

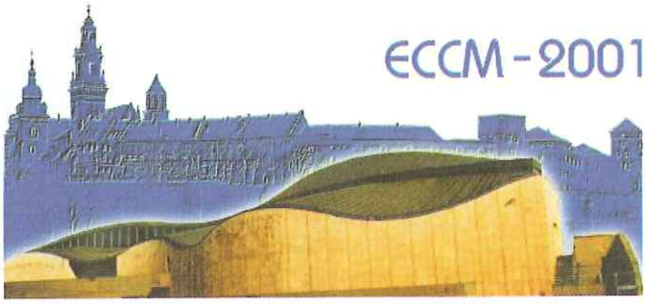
ECCM 2001
2nd European Conference on Computational Mechanics

Following the success of the European Conference on Computational Mechanics (http://www.statik.bauwesen.tu-
muenchen.de/ECCM"ECCM'99), which was organised in Munich, Germany on August 31-September 3, 1999, the 2nd Conference ECCM-2001 will be held in **Cracow, Poland** on **26-29 June, 2001**.

The conference is organised by the Department of Technical Sciences of the Polish Academy of Sciences , the Polish Association for Computational Mechanics and TU Cracow under the auspices of the ***International Association for Computational Mechanics*** and the European Community on Computational Methods in Applied Sciences
(ECCOMAS).

The Conference will bring together researchers and practising engineers, professors and students from all European countries as well as guests from overseas. The scientific part of ECCM-2001 will be focused on Mini-Symposia devoted to different topics associated with computational methods in mechanics of solids, structures and coupled problems, and with their applications in engineering. A rich and attractive cultural and touristic programme will be offered to the conference participants and accompanying persons. It will give them a chance to appreciate the atmosphere of Cracow and the region.

ECCM-2001
Cracow University of Technology
Warszawska 2431-155
Kraków POLAND
Phone/fax: +48-12-628 25 14
E-mail:mailto:eccm@pk.edu.pl
eccm@pk.edu.pl
Conference web-page:
http://www.pk.edu.pl/eccm ●



The 33rd Solid Mechanics Conference, SolMech 33, 2000

The 33rd Solid Mechanics Conference, SolMech 33, 2000, will be held in **Zakopane, Poland**, a renowned resort at the foot of Tatra Mountains from **5 - 9 September 2000.**

Following a long tradition, going back to the first Polish Solid Mechanics Conference in 1953, the objective of the 33rd Solid Mechanics Conference SolMech 33 is to bring together researchers engaged in all major areas of contemporary mechanics of solids and structures. The program of the conference will include a number of invited lectures and contributed papers.

Main Subjects are to include:
Mechanics and Thermodynamics of Solids with Microstructure, Inelastic Response of Materials and Structures, Geomechanics, Structural Mechanics, Sensitivity and Optimization, Instability and Localization Phenimena, Fracture Mechanics, Damage, Fatigue , Dynamics of Solids and Structures, Nonlinear Waves, Composites, Porous Media, Biomechanics, Stochastic Methods, Computational Methods and Experimental Methods.

For any further information please contact:
Organizing Committee SolMech 2000,
Institute of Fundamental, Technological Research,
Centre of Mechanics and Information Technology,
Swietokrzyska 21, 00-049,
Warszawa,
POLAND.
Phone : (+48 22) 826 88 02
Fax: (+48 22) 826 98 15
E-mail: solmech@ippt.gov.pl
WWW:
http://bimbo.ippt.gov.pl/solmech ●

APCOM ´01 First Asian-Pacific Congress on Computational Mechanics

During the last millennium, a series of Asian-Pacific Conferences (APCOM) were held successfully in Hong Kong (1991), Sydney (1993), Seoul (1996) and Singapore (1999). By the end of the last millennium, it was decided to form the Asian-Pacific Association for Computational Mechanics because of the extensive activities in the field of computational Mechanics within the Asian-Pacific region.

This we now host the First Asian-Pacific Congress on Computational Mechanics - APCOM´01 to be held in **Sydney, Australia** during **October and November 2001**. APCOM will be held every three years.

The theme of the first congress of the Asian-Pacific Association for Computational Mechanics in the new millennium is 'New Frontiers For New Millennium'.

The specific aims of the congress are:

- To bring together academics, researchers and practitioners to discuss the developments in the field of Computational Mechanics during the last millennium and to set new directions for further developments.
- To bring together engineers, scientists and applied mathematicians in order to encourage cross-fertilization of ideas and techniques relevant to Computational Mechanics.

Dr. N. Khalili
Secretary, APCOM'01
School of Civil and Environmental Engineering
University of New South Wales
Sydney NSW 2052, Australia
FAX: 61-2-9385-6139
Email: n.khalili@unsw.edu.au

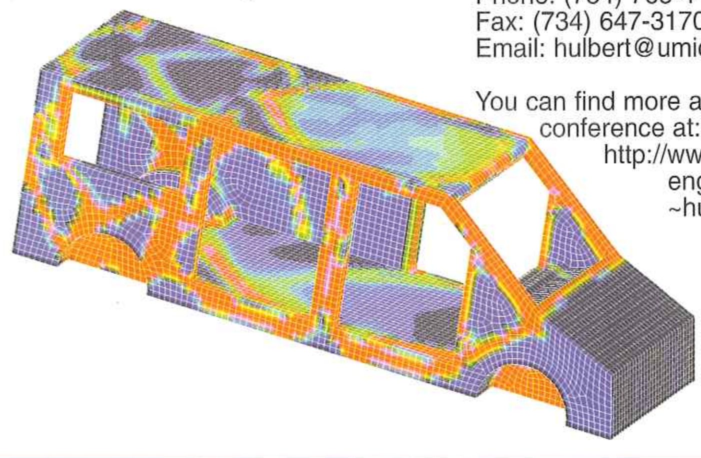
For more information, please visit Web site: http://www.civeng.unsw.edu.au/conferences/apcom01 ●

6th Official Congress of the U.S. Association for Computational Mechanics

This is the sixth official Congress of the U.S. Association for Computational Mechanics (USACM). It will be held at the Hyatt Regency Dearborn, in Dearborn, **Michigan, U.S.A.** on Wednesday through Friday, **August 1-3, 2001**.

A Post-Conference Short Course will be offered on Saturday August 4.

Since the first U.S. National Congress on Computational Mechanics (USNCCM), held in 1991, the USNCCM has developed into an international Congress, with participation from Europe, South America and the Pacific Rim. The 6th Congress will continue this international tradition, particularly as the 6th Congress endeavours to strengthen ties with the automotive and manufacturing industries. Based upon the location in the heartland of the U.S. automotive and manufacturing industries we envision active involvement in the Congress by industry.



Thus, the 6th USNCCM will cover a wide, international spectrum of fundamental research in and practical application of computational mechanics.

Call for MiniSymposia Organizers: People interested in organizing a MiniSymposia should contact Prof. Greg Hulbert with their proposed MiniSymposia topic. New Symposia are being proposed continually; thus it is important to communicate your proposal prior to the September 15, 2000 deadline.

For further information regarding both the conference and MiniSymposia, please contact:

Gregory M. Hulbert
Mechanical Engineering Department
Computational Mechanics Laboratory2250 G. G. Brown University of Michigan
Ann Arbor, Michigan
48109-2125 USA
Phone: (734) 763-4456
Fax: (734) 647-3170
Email: hulbert@umich.edu

You can find more about the conference at: http://www.personal.engin.umich.edu/~hulbert/usnccm6.html ●

First M.I.T. Conference on Computational Fluid and Solid Mechanics

As the importance of computational modelling and analysis in Engineering and the Sciences has grown, an increasing number of conferences on computational methods and applications have been conducted.

With this Conference, M.I.T. invites you to share experiences in the broad areas of computational modelling and analysis of fluids, solids and structures, and multi-physics phenomena, as encountered in any application. It is to be held at the **Massachusetts Institute of Technology, Cambridge, M.A.** from **12 - 14 June 2001.**

Objectives:
To bring together researchers and practitioners from around the world to assess the state-of-the-art of high performance computing and to set important directions for further research and development.

For further information, contact:

Klaus-Jürgen Bathe
Email: kjb@mit.edu
Tel: (617) 253-6645
Fax: (617) 253-2275 ●

conference diary planner

21 - 25 August 2000	**16th IMACS World Congress 2000** *Venue:* Lausanne, Switzerland Contact: Fax: (1) 732-445 05 37, Email: imacs@cs.rutgers.edu WWW: http://IMACS2000.epfl.ch
5 - 9 September 2000	**33rd Solid Mechanics Conference** *Venue:* Zakopane, Poland Contact: Tel: (48) 22 - 826 88 02, Fax: (48) 22 - 826 98 15, Email: solmech@ippt.gov.pl, WWW: http://bimbo.ippt.gov.pl/solmech
6 - 8 September 2000	**CST 2000 - 5th International Conference on Computational Structures Technology &** **ECT 2000 - 2nd International Conference on Engineering Computational Technology** *Venue:* Leuven, Belgium Contact: Tel: (44) 131-332 10 20, Fax: (44) 131-332 3060, Email: buro@saxe-coburg.co.uk WWW: http://www.saxe-coburg.co.uk
11 - 14 September 2000	**ECCOMAS 2000 - European Congress on Computational Methods in Engineering and Applied Science** **COMPLAS 2000 - 6th International Conference on Computational Plasticity** *Venue:* Barcelona, Spain Contact: Tel: (34) 93-401 64 87, Fax: (34) 93-401 65 17, Email: eccomas2000@cimne.upc.es WWW: http://www.cimne.upc.es/eccomas
25 - 27 September 2000	**MS'2000 - International Conference on Modelling and Simulation** *Venue:* Las Palmas de Gran Canaria, Spain Contact: Tel: (34) 928 - 45 19 25, Fax: (34) 928 - 45 88 11, Email: ims2000@dma.ulpgc.es WWW: http://www.dma.ulpgc.es/ms2000
26 - 30 September 2000	**ECMI 2000 - The European Consortium for Mathematics in Industry** *Venue:* Palermo, Italy WWW: http://www.itdf.pa.cnr.it/ecmi2k
28 - 30 September 2000	**3rd International Congress for The Croatian Society of Mechanics** *Venue:* Cavtat / Dubrovnic, Croacia Contact: Tel: (385) 1 - 61 68 540, Fax: (385) 1 - 61 68 187, Email: jasna.biondic@fsb.hr
16 - 18 October 2000	**APCS 2000 - 6th Asian Pacific Conference on Shell and Spatial Structures** *Venue:* Seoul, Korea Contact: Tel: (82) 331-290 75 53, Fax: (82) 331-290 75 70, Email: tjkwun@yurim.skku.ac.kr
20 - 23 November 2000	**MENCIS 2000 - 1 Congress on Numerical Methods in Social Sciences** *Venue:* Barcelona, Spain Contact: Tel: (34) 93-401 64 87, Fax: (34) 93-401 65 17, Email: eccomas2000@cimne.upc.es WWW: http://www.cimne.upc.es/mencis
7 - 12 January 2001	**VIACMAG - 10th International Conference on Computer Methods and Advances in Geomechanics** *Venue:* Tucson, Arizona Contact: Tel: (1) 520-621 3054, Email: epd@engr.arizona.edu
12 - 14 June 2001	**First M.I.T. Conference on Computational Fluid and Solid Mechanics** *Venue:* Cambridge, M.A., U.S.A. Contact: Tel: (1) 617 - 253 66 45, Fax: (1) 617 - 253 22 75, Email: kjb@mit.edu WWW: http://www.firstmitconference.org
26 - 29 June 2001	**ECCM - 2001 - 2nd European Conference on Computational Mechanics** *Venue:* Cracow, Poland. Contact: Tel/Fax: (48) 12 - 628 25 14, Email: mailto:eccm@pk.edu.pl WWW: http://www.pk.edu.pl/eccm
1 - 4 August 2001	**Sixth US National Congress on -Computational Mechanics** *Venue:* Dearborn, Michigan, U.S.A. Contact: G. Hulbert, Tel (voice): (734) 763 44 56, Email: hulbert@umich.edu WWW: http://www.personal.engin.umich.edu/~hulbert/usnccm6.html
Oct / Nov 2001	**APCOM'01 - First Asian-Pacific Congress on Computational Mechanics** *Venue:* Sydney, Australia Contact: Fax: (61) 2 - 93 85 61 39, Email: n.khalili@unsw.edu.au WWW: http://www.civeng.unsw.edu.au/conferences/apcom01/
14 - 16 July 2002	**IABMAS'20 - First International Conference on Bridge Maintenance, Safety and Management** *Venue:* Barcelona, Spain Contact: Tel: (34) 93-401 64 87, Fax: (34) 93-401 65 17, Email: iabmas02@cimne.upc.es
21 - 26 July 2002	**b'02 IFAC - 15th World Congress** *Venue:* Barcelona, Spain Contact: Tel: (34) 93-401 64 87, Fax: (34) 93-401 65 17, Email: secretariatnoc@b02.ifc2002.org