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Combating the thaumasite threat to concrete

BRE

The thaumasite form of sulfate attack (TSA) can be a serious threat to concrete structures if inappropriate constituents are used in aggressive sulfate ground conditions. Therefore, a greater understanding and recognition of this problem is needed.

Structures made of concrete specifically designed to provide good sulfate resistance in accordance with even quite recent guidance can still be affected by TSA. The full extent of the problem is as yet unknown, but it has the potential to affect a wide variety of structures including:

- concrete foundations and floor slabs exposed to sulfate-bearing ground
- roads and sub-bases
- tunnel linings and sewer pipes.

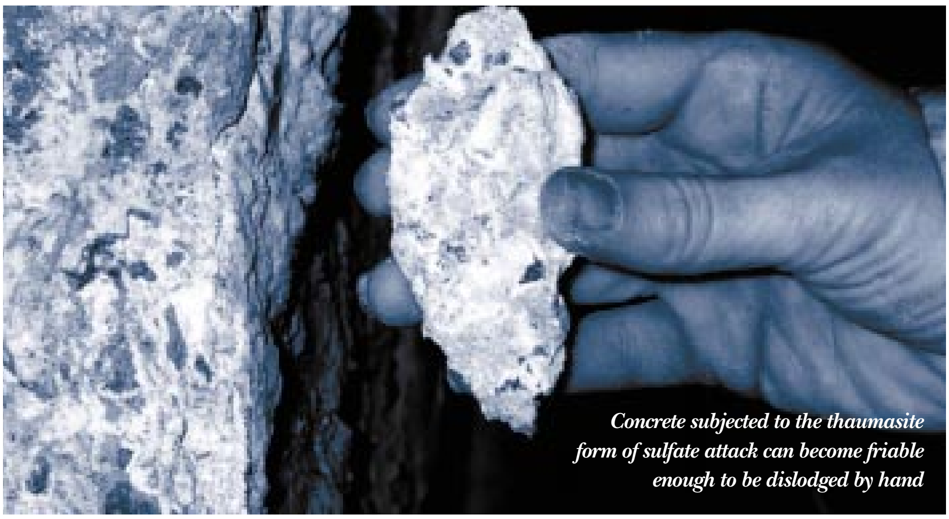
Thaumasite was first identified as a deterioration product in concrete in the USA in the 1960s. Since then a growing number of cases of concrete degradation involving thaumasite have been identified worldwide, with many in the UK.

During the late 1980s and early 1990s, BRE discovered several UK cases of severely attacked buried concrete, where the hardened cement paste matrix had been completely replaced by thaumasite transforming the fabric of the concrete into a soft incohesive mush. More recently, severe TSA has been found in the foundations to a number of motorway bridges in the west of England, prompting a national review by an Expert Group convened by the UK Minister for Construction. Following extensive research supported by the UK Government, new BRE and British Standards Institution guidance is now in place to deal with the problem.

Distinguishing features

The minerals most commonly reported as products of sulfate attack are gypsum and ettringite. As analytical techniques have become more sophisticated over the years, a growing number of recent cases are identifying thaumasite as a third reaction product.

TSA differs from conventional sulfate attack in that it is the calcium silicate hydrates (CSH) in the hardened Portland cements that are targeted for reaction and not the calcium aluminate hydrates. CSH is the main binding agent in all Portland cements including sulfate-resisting Portland cements. The replacement of CSH by thaumasite is accompanied by a reduction in the binding ability of the cement in the hardened concrete. The result is a loss of strength and transformation of the cement paste into a mushy, incohesive mass.



Concrete subjected to the thaumasite form of sulfate attack can become friable enough to be dislodged by hand

The circumstances

For thaumasite to form, all the components comprising this mineral (sulfate ions, carbonate ions and calcium silicate or calcium silicate hydrate) must be available. A prominent source of carbonate ions is limestone present in the building material itself as an aggregate or filler, although cases of TSA are known where the carbonate has been supplied by external sources.

An external source of sulfate ions is also required and the reaction relies on copious amounts of water. So, concrete foundations containing limestone aggregates in wet sulfate-bearing ground would be considered to be at the highest risk of TSA.

Typically, TSA occurs in the concrete of foundations to buildings and structures, which are either fully or partially buried, so evidence of TSA is always hidden below ground and cannot be detected by routine above-ground inspections.

Conference

Although TSA has become a high-profile issue in the UK in recent years, and has been found in some other countries, the level of awareness of this form of sulfate attack remains low on the international stage. To raise international awareness, and to provide a forum for dissemination of research and exchange of ideas, BRE is arranging the First International Conference on Thaumasite in Cementitious Materials. The conference will take place at BRE's UK headquarters from 20 to 22 June 2002.

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in brief

Further developments in new Framework programme
The CEC has recently approved five new research programme proposals setting out the scientific priorities for the next Framework Programme. The new proposals are intended to set out a clearer picture of the organisation, working arrangements and priorities for the programme.

The five proposed programmes are:

- integrating and strengthening the European Research Area (12,505 million)
- structuring the European Research Area (3,050 million)
- independent research in the nuclear field (900 million).

Two other programmes (totalling 1045 million) will cover the work of the JRC.

The JRC's role in ERA
The CEC has just published a report on the future role of the JRC with respect to the plans for a European Research Area (ERA). The document is called 'Fulfilling the JRC's mission in the ERA'.

The report can be found in full at: http://**www.jrc.org/download/comm_010420_en.pdf**

"ENBRI brings together the principal Building Research Institutes of the European Union (EU) and of the wider European Economic Space (EES), for the benefit of the world of construction."

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Bending strength and stiffness of high-temperature-dried Norway spruce timber

In recent years, the interest in high-temperature drying of timber has increased in Europe for several reasons; these include reduced drying time, less energy consumption and probably less distortion. However, an important issue is whether the strength and the stiffness are affected by drying at high temperatures. Published studies show a variety of results.

In a recent study carried out at SP the influence of high-temperature drying on the bending strength and the stiffness of Norway spruce timber was studied. Comparisons were made with timber dried under conventionally low temperatures. Bending strength and modulus of elasticity were determined according to EN 408, the standard method for structural timber (four-point bending). The weakest point, determined by a Cook Bolinder strength grading machine, was centred between the loading points.

Three samples, each consisting of approximately 200 specimens with a cross section of 45 x 145 mm were dried with different drying schemes: one high-temperature (HT) drying scheme (115°C); one combined low/high-temperature (LHT) scheme (70°C/120°C); and one conventional low-temperature (LT) drying scheme (75°C). To obtain three equal samples, all material was passed through a Cook Bolinder strength grading machine before drying. With the flatwise modulus of elasticity measured by this machine, the three samples with similar stiffness were obtained.

The bending strength for the material dried by the different drying methods is shown in Table 1. LT-dried material displayed significantly higher bending strength compared to the material dried by the other two methods. The LHT drying scheme, on average, decreased the bending strength by 11.5% compared to 9.5% for HT-dried timber. Comparison is made with the conventionally LT-dried timber. It seems possible that different HT drying schemes affect the strength properties of timber more or less severely. Also, the fifth percentile value of the bending strength seemed to be considerably influenced by the HT drying (see Table 1). The fact that the fifth percentile values are decreased makes the results especially important as these values are the characteristic strength. As nearly 200 specimens were tested within each group the results appear reliable.

Most failures, when tested in bending, start at knots. However, this is not always a knot within the constant moment region. One speculation is that the loss in strength for HT-dried timber is related to high temperature effects on the material around knots.

No significant influence of HT drying on the modulus of elasticity was found. The bending strength, but not the bending stiffness, seems to be influenced by HT drying. This may lead to practical consequences for the use of HT-dried timber as in many cases strength grading is based on the relationship between strength and stiffness. No effect of HT drying on the density was found.

A new study comprising spruce material dried by six different drying schedules in temperatures ranging from 70°C to 125°C is ongoing. Bending strength, bending stiffness, tension strength and tension stiffness are being measured. Preliminary results confirm the results of the first study. The bending strength is decreased by high temperature drying but the bending stiffness remains unaffected.

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	Bending strength					t-test	
	N	Average [MPa]	Std. dev. [MPa]	Fifth percentile (normal)	Fifth percentile (non-parametric)	HT	LHT
LT	180	50.9	13.9	27.3	30.4	1	1
LHT	188	45.1	13.5	22.1	22.3	0	
HT	194	46.1	14.1	22.1	25.8		

Table 1 Bending strength at 12% moisture content for the material dried with different drying methods. N is the sample number in each group. The fifth percentile values shown are calculated as normally distributed and without assumed distribution (non-parametric). Also the results of a t-test with 5% confidence level are shown ('1' denotes statistically significant).

An analysis model of fire hazard

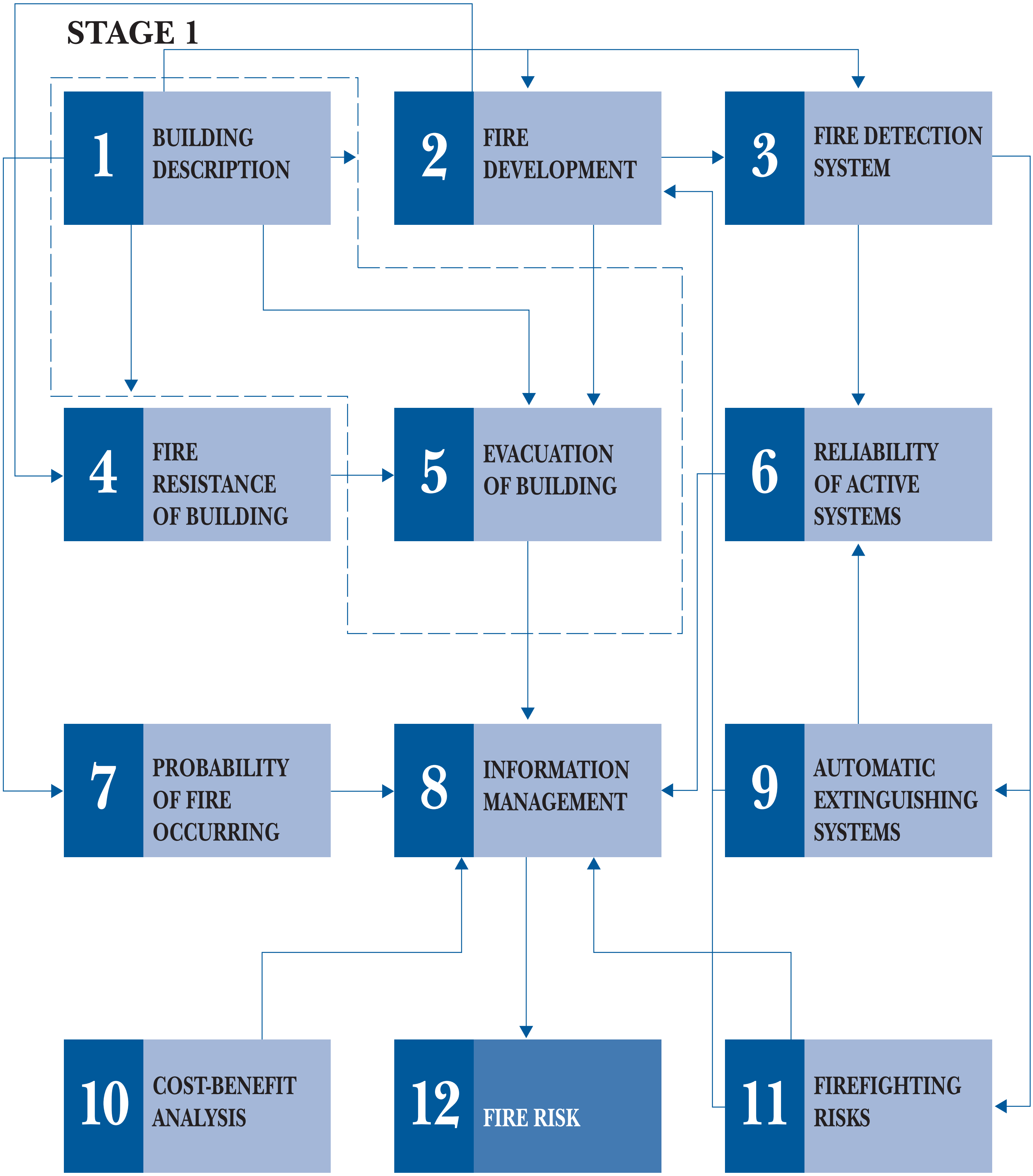

Figure 1 Flowchart for fire risk analysis in buildings

in buildings

Some time ago LNEC launched an overall analysis model of fire hazard in buildings, formed by 12 partial models (see Figure 1). Future application of the model is planned to be as comprehensive as possible, in order to be used as support to future regulations.

At an intermediate stage, the model will make it possible to determine the evacuation time of a specific building subject to fire and will give the possibility of verifying if there are any occupants who, due to the fire, cannot leave the building.

When fully developed, the model will enable the determination of the fire hazard of any building.

Two of these partial models have been developed: the model describing the building and the model of the building evacuation (partial models 1 and 5). The computer implementation of the latter model, in Visual Basic, is to be completed before the end of 2001.

From a geometrical and physical point of view, the building description model is applicable to buildings of up to 30 floors and 10 stairways. This makes it possible to represent any building with an irregular plan. The model also enables the representation of obstacles within the building and the location of fire detectors and occupants when a fire occurs. It also allows the production of a schematic drawing of the building and of the data introduced into the model.

The building evacuation model considers:

- individual and a macroscopic analysis of the occupants' movements (the individual analysis is essential for obtaining a coherent model of simulation of the occupants' actions)

- velocity variation according to occupants' density and occupants' movement in any direction conditioned only by obstacles

- analysis of interaction of occupants' flows in confluence zones

- analysis of overcrowding situations, by modelling the phenomenon of arch formation next to openings in high-density situations

- analysis of the position of doors (this analysis is associated with the possible existence of automatic closure devices, the time they take to close after the door has been opened and the proximity of occupants that pass through the openings where the door is placed)

- identification of each occupant throughout the entire evacuation process and considerations of some behavioural aspects of the occupants.

Such behavioural aspects refer to the occupants' reaction to parameters associated with the fire (temperature, radiation and visibility) which may block exit routes forcing occupants to look for and to find alternative paths. These factors depend on the information provided by the fire development partial model (partial model 2) which will subsequently operate in conjunction with the others.

From the visibility point of view, two separate issues are considered:

- environmental conditions (existence of smoke and consequent diminution of visibility)

- possible hiding of signals by obstacles.

Information on occupants' behaviour is to be developed in co-operation with the fire services, by collecting information from occupants involved in fires, as well as through the completion of experiments on human behaviour and arch formation in a fire context.

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The R&D Programme 'Climate 2000 – Building constructions in a more severe climate'

Norwegian Building Research Institute

Climatic factors such as rain and snowfall, wind loads, sun exposure and air temperature cause serious damage to buildings and structures every year. With the threat of global warming there are expectations that worse is to come. An increasing number of observations indicate an increase in global temperature and other changes in the climate system – see the Third Assessment Report of WG I of the Intergovernmental Panel on Climate Change (IPCC).

The trend for the last 10-15 years, with milder and wetter autumns and winters and more storms along the coast of Norway, is expected to increase during the next decades (estimates from a climate change scenario for Norway for the next 50 years, presented by the research project *RegClim*). Potential implications of climatic change on buildings being constructed for the next decades need to be studied today. The insurance costs of the hurricane that struck the north-west part of Norway on New Years Day 1992 amounted to about 2 billion NOK. Large snow loads on roofs during the winter of 1999/2000 contributed to the collapse of several buildings in the northern part of Norway. In eastern Norway and along the south coast and immediate inland districts it rained for very long periods last autumn.

The large amounts of precipitation resulted in damage to buildings never damaged before. None of these single weather events can directly be ascribed to climate change, but they do remind us of how vulnerable society has become when faced with major climatic variations and severe weather conditions.

The effects of future climate change could have a significant impact on society in several areas including the built environment. An even more severe climate in our area implies that a thorough knowledge of fundamental features of the different climatic factors interacting on buildings and structures are more important than ever before. Scenarios for regional climate development under global warming, regarding increase in sea level, changes in temperature, precipitation, wind speed, vapour pressure and relative humidity and the frequency of severe weather events must be studied in order to be able to adjust to the changes. Doing so could minimise possible negative effects on the built environment. Climate change could have considerable impact on the return rates of 'extreme' weather events. Necessary margins of safety in Norwegian Building Regulations and Codes with regard to undesirable incidents must be reviewed regularly, in order to maintain a proper level of reliability.

Winter in Oslo (photo: Thomas Thiis, Norwegian Building Research Institute)

Investigations carried out by the Norwegian Building Research Institute have shown that the costs involved in the repair of building damage in Norway amounts to 5% of the annual investment capital in new building. We note with regret that the amount of damage has not decreased in later years and many types of damage related to different climatic impacts frequently recur. More than 75% of the total amount of investigated damage are water and moisture damage. Problems related to moisture conditions in buildings may safely be said to be one of the greatest challenges facing the construction industry today.

The above factors form the background for the Norwegian research programme 'Climate 2000 – Building constructions in a more severe climate', initiated and managed by the Norwegian Building Research Institute. The project will be carried out in close collaboration with building authorities, major building contractors, owners and businesses, universities and other R&D institutes. The estimated total cost for the programme is 15 million NOK (programme period 2000-2003). The programme consists of 12 different projects, all of which are related to the assessment of impacts of the different climatic factors on building materials and constructions.

The principal objective of this programme is to develop reliable solutions for buildings that offer better resistance against impacts from different climatic factors, to survey potential implications of climatic change in the built environment and how to adapt ourselves to these changes. The dissemination of knowledge obtained from the programme will be emphasised in particular. One key route will be through a special programme website at www.byggforsk.no (under construction). Norway is a country with great variations in local climatic loads. Hopefully, this research programme will also contribute to a greater awareness of the need for local climate adaptation of the built environment and that such awareness will ensure better buildings in the future. To consider and respect the local climatic conditions is cost-effective in the long run!

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Visualising the progress of a construction project

VTT and Eurostepsys Oy have developed software that visualises the progress of a construction project. The software brings together information from computerised 3D models and project schedules. The solution is the first one operating in standard microcomputers that puts together standard 3D building model with construction schedule.

Modern construction projects depend on the efficient participation and skills of teams from a number of companies, and the project manager works strongly as an integrator with other key individuals. To be such an integrator means both technical solution integration and team integration. Communication needs are clearly much higher than they used to be and they cannot be solved in a simple manner by just providing access to all possible project data.

Visualisation allows the teams to review oncoming stages of the work in a way that can be easily and unambiguously discussed and understood by everyone. This can be effectively achieved by providing self-explanatory computer visualisations of the product (building) and construction processes.

The software known as 4D makes the planning of construction projects an interactive process. The interaction facilitates full use of the skills of participants, resulting in immediate cost savings. If the workplan contains mistakes, these can be discovered immediately in visualisation sessions.

The software makes it possible to simulate the building schedule day by day. The stage that will be reached at the construction site can be seen on the computer display. The easiest way to use the software is to access it by using an internet browser, but it is also possible to use it in virtual-reality studios where it is possible to walk in a virtual version of the site and see what the site looks like.

Pilot studies

Practical pilot studies of the use of 4D software have been carried out at an office construction site in Helsinki. There are two prerequisites for applying the software: architectural 3D information on the structure of the building has to be available in the IFC data exchange format; and the project schedule has to be prepared using standard project management software package.

Pilot studies and additional presentations to the company staff participating in the pilot studies have demonstrated clearly the value-adding potential of the developed solution for modern construction business. An example of a question for which a clearly improved understanding can be reached with the use of 4D software is 'Is the master schedule of the project feasible and realistic?' The progress visualisation has a self-explanatory nature and even the characteristics of the most complicated schedules can be explained and understood without difficulties. This is resulting in most promising benefits from which examples are less re-work, less waiting, less extra resources, efficient procurement and safer construction site.

The software development has been carried out as a part of an extensive EU research project (DIVERCITY, IST-1999-13365) that seeks to develop innovative solutions for facilitating communication and co-operation between building project participants by means of applying virtual-reality technologies. There are 10 participants from six countries in the project.

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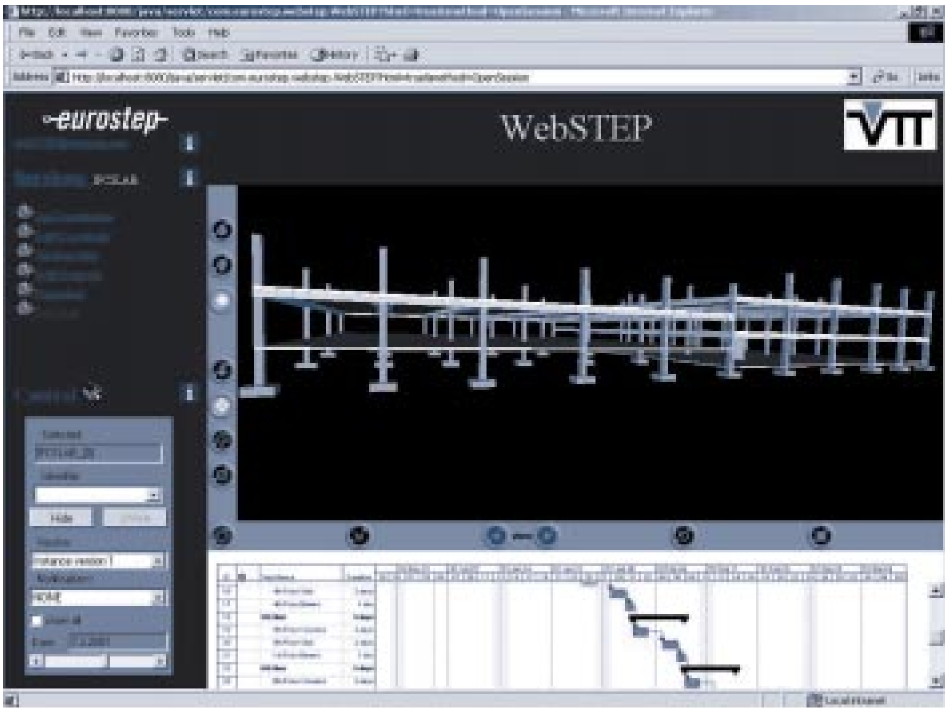

4D schedule simulator puts together 3D building model and the master construction schedule prepared with standard software packages

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