Saving of Towns Endangered by Cellars

Protection des Villes Menacées par les Cavités

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SYNOPSIS The planned, centrally controlled research-, projecting and executive methods applied for the elimination and prevention of damages caused by cellars in great masses and endangering more and more towns in Hungary can serve as a utilizable experience for other towns having similar difficulties.
With the neutralization of the cellar systems the greatest task is the choice and the practical introduction of economical and mechanized technologies complying the best with the geotechnical, surface loading and urban circumstances for intervention in the cellars and not the research of new calculation and dimensioning methods.

INTRODUCTION

In some Hungarian towns having a great historical past, prosperous and having a developing industry even in our days - where the morphological conditions and the geological and hydrogeological circumstances made it possible, cellar networks extending to the great part of the settlements, moreover coherent cellar systems were formed out in the course of the centuries. These underground structures served for the satisfying of more demands: they were used for storing of wine and for other economical purposes, at the time of the Turkish occupation they were utilized for escaping from the enemy, later they became mines of building material.
The deep cellars and cellar systems can be found in such a magnitude that they meant in the last decades already a special source of danger for some towns.
The majority of the cellars came into being in the XVII. and XVIII. centuries. In the course of the centuries these were either forgotten or by later extensions and connections they developed to be complicated cellar systems.

GEOMETRICAL LOCATION OF THE CELLARS, THE GEOLOGICAL BASIS OF THEIR ENVIRONMENT, THEIR SIZE AND STATE

A part of the cellars was built in weakly limy bount sand of the Pliocene /Pannon/ age. Above the sand slope detrital of clayey and silty basic material took place. The other part of the cellars can be found in riodacite tuff, or in Pleistocene limestone and in Miocene limy sandstone. The cellars built into sand were - almost without exception - reinforced at the time of their construction, because this sand had almost no cohesion. The cellars built into tuff and into limestone are generally without reinforcement. Cellars were made in loess and in sandstone too.
The profile of the cellars is very changing concerning both their shape and area. Cellars of a profile of 6-15 m² were built with a length of 3o-4o m, in the depth of 6-2o m under the surface, placed sometimes on different levels above each other. In their location related to each other generally no regularity can be discovered. /as shown in Fig.1/

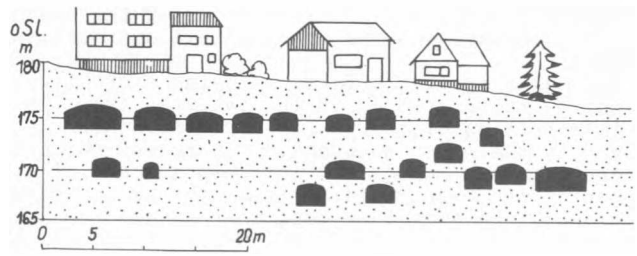

Fig.1 Cellars located in more levels within range

As to their ground plan these cellars and cellar systems are in no conformity with the boundaries of the buildings and parcels, they extend moreover under the great part of the public areas. /as shown in.Fig.2/
Number of the cellars requiring an intervention is 4.500, their length is 25o km, their space is 3 million m².
It is often that the buildings above the deep cellars were transformed, built off, then reconstructed and so the cellars were separated from the superstructures.

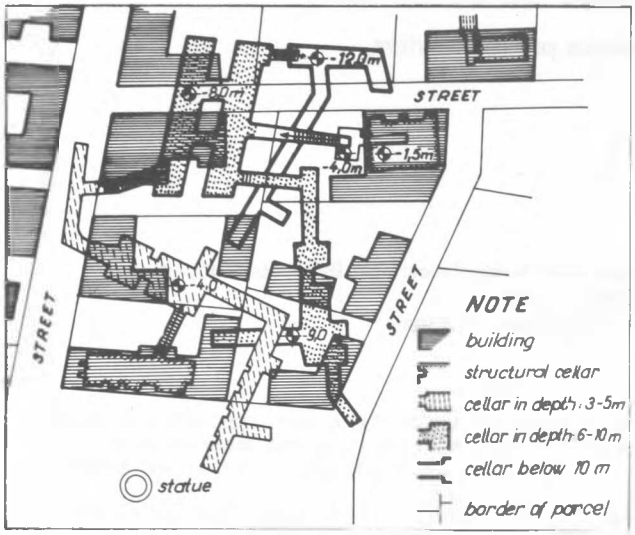

Fig.2 In the ground plan location of cellar systems no regularity can be found

Causes of the deterioration of cellar consistency and increase of the danger situation

The cellars after a silent "presence" of more centuries, have called the attention to themselves always more frequently since the seventies. Sinking of roads, collapsed buildings, traffic deviations occured.
In our days the damages caused by cellars present themselves concentrated in space and time. The cause of this is already mostly wellknown, this can be summarized as follows:
In the XI. century the started urbanization presented itself at first by increase of the magnitude and weight of the buildings, later on the vehicles of great axle weight and of great velocity appeared. In consequence of this the limiting walls and concamerations of the caves get an always increasing dynamical and statical load.
The water is also a factor playing a great role in the deterioration of the cellars. With the introduction of the public works for water supply the water consumation increased which the drain of the sewage did not keep abreast. The use of the home wells draining the ground water ceased, the same time much more sewage as previously had to be dried. Below the towns the level of the ground water started to raise. We have to take into consideration the waters originating from the frequent faults of the old supplying pipelines and the lack of the leading off of rainwaters too. After the showers of great intensity the cellar collapses and road fallings presented themselves almost in a time-table like manner.
A significant factor in the deterioration of consistency of the cellars is the lack of maintenance, the ageing of the structural materals.

The works of the cellar eliminating organization

The acceleration of the deterioration of the cellar-consistencies presented itself as an elemental calamity in the beginning of the seventies.
The elimination of the catastrophic situation required measures on governmental level and the co-operation of the society.
In order to solve the tasks in an effective way a State Committee was formed in 1974 which determined the sequence of the tasks to be executed and assured for them the financial and technical conditions.
The arrangement of the underground spaces cannot be handled evidently separated from the structures on the surface.
The new character of the cellar elimination works had a mobilizing effect on the Hungarian technical public life which fact presented itself by the execution of two conferences and of a successful national competition.
On these events the research methodics of the unknown cellar- and cave-systems, the way of the preparatory and projecting works, the choice of the most economic neutralizing and reinforcing technologies, finally the new utilization possibility of the cellar spaces came into prominence.

PREPARATORY-PROJECTING

Before the designing a many-sided preparation and an economical projection is necessary. From these tasks the most importants are following.

Geodetic survey of the cellars

Both the research of the caves and the designing need an exact geodetic survey. On the cellar surveys is based the realization map too, prepared at the end of the cellar works. This contains the most informations about the works under the surface and is the base of the future maintenance.

Research and exploration of unknown cellars

Unfortunately the urban environment did not render an ideal field, a favourable underground model for any of the most rapid geophysical research methods /disturbed underground, public works, heat emission of buildings, microseismicity caused by vehicles, etc./.
Until now we have tried to use the following geophysical methods: geoelectrical measurements, seismic researches, thermovision, ultrasonic /acoustic/ method, gravimetric and magnetometric method and geothermic measuring procedure.
For an independent evaluation, for a concrete indication of a cave non of these methods has proved to be appliable.
Now we are doing the cave research first of all with the destructive method, i.e. with drilling, probing and afterwards with exploration. We use the geophysics only for preliminary information purposes.

Engineering geological mapping, geotechnical investigations

The knowledge of the geological, geotechnical and hydrological medium containing the cellars and caves does not help only in the limitation of the research area, but influences to a large extent the method of the reinforcement or of the elimination too.
With the execution of the works the elimination of the danger situation can not be considered as finished. The causes of the deterioration are to be neutralized in order to make a stop to the

process in due time. A part of the causes can be deduced from the geotechnical, rock mechanical, hydrological and morphological conditions which are explored by the geotechnical and engineering geological researches.
According to the above points of view were the special engineering geological and geotechnical maps prepared in the scale of 1:5oo - 1:1oooo.

Mapping of public works, translocations of traffic,examination of the state of buildings, official and legal measures

Also the following preparative activities indicate the tight connection of the cellar systems and of the surface.
In possession of exact maps about the service conduits the disturbances in the public services can be minimalized besides the cave-researching drillings and the civil engineering-mining interventions which are part of the executive works.
The translocation of the main traffic in the city from those areas having cellars below belongs to the activities antecedent to the danger of life.
The damages caused by cellars present themselves mostly on buildings and roads and can be brought into connection directly or indirectly with the deterioration of the state of the cellars.
Frequently the deformations and damages observed on the upper structures of the buildings show the presence of cellars. Therefore systematical survey of the state of buildings is necessary.
In connection with the tolerance of the executive works related to the cellars, with the distribution of the expenses and with the ownership of the reconstructed cellars a lot of legal regulations and measures of the authorities were necessary.

DESIGNING WORKS

Eliminations

The best method of the elimination of the cellars is the backfilling. The most important requirements concerning the backfilling material are as follows: its bringing down should not need much manpower and should disturbe only minimally the life of the town, the basic material should stand at disposal in the vicinity in great quantities and should be cheap, should not demand possibly any adhesives, the material should be the nearest to the soil- and rock conditions of the natural environment, as well as to its load bearing capacity.

Designing of reinforcements

The essence of the projection is the assumption of the standard loading position and of the statical model approaching best the reality.
For the traditional reinforcing structures /with bricks,monolyte concrete/ the classical dimensioning method is applied, so the cellarprofile dimensioning is not effected as with an embedded or with a hinged arch structure but as a retaining wall and vault /for active-passive earth pressure, soil weight, surface load/.
In case of reinforcements made of modern monolyte reinforced concrete structures and of prefabricated elements resp. the dimensioning as an embedded or versatile arch structure is applied.
The stresses of the wall are calculated by computer. The mosaic /finite elements/ method means a modern dimensioning which is based on the mathematical description of the displacement functions. Some modern reinforcing procedures - as e.g. that one with the rock-screw - do not have any satisfying dimensioning method as yet.
For some reinforcing methods - by entering of different loads and profile dimensions and with knowledge of the geotechnical and rock mechanical data - such a dimensioning nomograph can be elaborated from which e.g. the searched wall thickness and iron quantity can be determined by a simple reading.
According to the experience gained until now there is a lot of subjectivity of the designer when entering the loads and judging the statical model from which - because of cautiousness - generally the overdimensioning is the result.
With the reinforcement the following must be taken into consideration: possibility of the mechanization of the method, economy of the applied material, the later utilization conditions /water tightness, approach, aesthetics, ventilation, etc./, durability of the built in material.

EXECUTION OF THE CELLAR ELIMINATION WORKS

Prevention of life-danger

From the character of the cellar problems results that we have to reckon always with building damages, faults of roads and of supplying conduits because of cellar collapses or with cellars requiring an immediate intervention which present themselves dispersed and unexpected. The method of intervention was at first the timbering, presently by the rapid, well mechanizable backfilling technologies a final solution can be achieved.

Eliminations

Backfilling with cement mortar: The cement mortar mixed on basis of the prescriptions will be brought down by gravitation or by a pump to the cellar space. Because of the technology the backfilling will be finished with changing mortar composition - by a closing and a roof resp. injection. Generally a back space injection is necessary for the neutralization of soil thinnings and cavities behind the brickset cellars.
In order to distribute and to bring down resp. the mortar different plasticizers will be mixed into cement mortar /barra fluid, bentonite etc./
The backfilling will be effected in two phases according to sections:

- in the first phase the backfilling must be made up to about 9o % of the whole cross section area;
- after the solidification of this the closing injection is to be made by strongly improved cement mortar.

The possibility of exit of the water and of the air from the injection space is ensured by a pipe built in at the highest point of the section.
Sand backfilling by hydromechanization: The sand originating from a near mine will be brought without any binding material hydraulically to

the cellar where the compacting effect will be achieved by water suction executed layer by layer. /as shown in Fig.3/

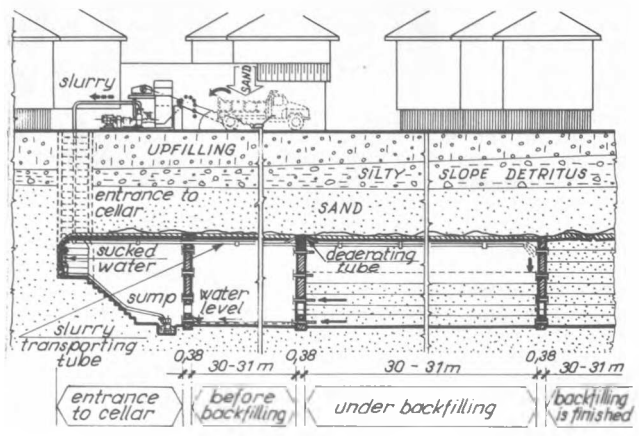

Fig.3 Technological process of the sand backfilling by hydromechanization

The technology makes the sectioning of the cellar to be neutralized necessary. Into the sectioning walls will be put seepage pipes equipped with filter and gate valve.
Backfilling by tuff concrete: Lean concrete of liquid consistency with tuff-powder additive material will be brought down in the gravitation or pumped way to the previously sectioned cellar space to be neutralized.
Injected backfilling by limestone crushing: Into the by limestone crushing filled and previously sectioned cellars a posterior injection will be effected by cement mortar /colcret/.
Backfilling by fly ash gas-concrete: The previously sectioned cellar spaces will be filled out by porous gas-concrete having a weak consistency filter fly ash additive in the gravitation or pumped way. The gas formation causing swelling will be achieved by the addition of an aluminium paste. The space outfilling effect is good because of the swelling character of the material.

Reinforcements

Traditional masonry: The cave reinforcement made by masonry is an old reliable method where eventually the walling material has changed but hand-made character of the work remained.
Gunite concrete technology: On the surface reinforced or without reinforcement a concrete made of classified additive material, with a suitably adjusted watercement-factor will be gunited with great pressure.
Monolithic concrete structure: It is equally known as a reinforced or not reinforced structure. The concrete of prescribed quality will be brought behind the casing /metal or wood/ formed out according to the necessary wall thickness by a low pressure pump.
Reinforcement by rock screw /roof screw/: From the roof boreholes will be drilled of a length of 1,5 - 2 m in radial direction with a spacing frequency determined by calculations in which besides injection rock screws will be placed. After getting solid the rock screws will be stressed on the washers below them and so the cellar environment of a thickness corresponding to the length of the rock screw will be drawn into load bearing.

Utilization of the cellar spaces

In the beginning of the planned cellar neutralization works the cellar systems below the towns were considered almost exclusively to be a source of danger and so from time to time cellars of greater dimensions became "victims"of the backfilling too. The utilization possibilities of cellars of good consistency and of great dimensions are considerable. This is supported by the following points of view too:

- Over the traditional utilizing possibilities more and more functions of the town life can be brought under the surface.
- The mechanizable and cheap reinforcing methods make the utilization of more and more cellars possible, in many cases with a more economic solution as the backfilling.
- The reinforced cellar can be controlled constantly technically, its state can be checked by the eye. It may represent less uncertainty for the surface projects.

Without any ambition to completeness the following utilization possibilities may come into question in case of the reinforced cellars: bomb-shelter storage, production of mushrooms, restaurant, clubs and youth clubs, placement of heating system, ageing cellars of champagne factories, sporting projects for schools and for the public, laboratories, conference halls, museum of stonework, in case of a suitable surface environment columbarium, tunnels for supplying conduits, subways, etc.

EXPERIENCES, PROBLEMS AND FURTHER TASKS IN CONNECTION WITH THE CELLAR WORKS

Control

The quality of the effected backfillings and the reliability of the space outfillings must be checked. One method is the application of the dynamic penetration test. The controls by test - concerning both the efficiency of the backfilling and the quality of the material - showed a lot of contradictions, the results are strongly scattered, though this procedure must be devoloped because of economical reasons.
Protection of the cellars after the intervention

Those damaging circumstances which caused the deteriorations in the cellar consistencies must be neutralized. These are first of all the effects of getting wet /from public works or from layer waters/ and the effects of the traffic.
Construction work above reinforced or backfilled areas

The urban construction works above the professionally backfilled or reinforced cellars are inevitable but necessary too. So the technical utilization of areas above the cellars raises geotechnical problems which deviate from the average, namely the medium involded into the load bearing - because of the reinforced or backfilled cellars - behaves itself as an inhomogeneous layer. At present we are continuing researches for the determination of the load bearing capacity of the reinforced or backfilled areas.