First European Conference on Earthquake Engineering and Seismology
(a joint event of the 13th ECEE & 30th General Assembly of the ESC)
Geneva, Switzerland, 3-8 September 2006
Paper Number: 1

SEISMIC HAZARD AND ALPINE VALLEY RESPONSE ANALYSIS : GENERIC VALLEY CONFIGURATIONS

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SUMMARY

In the framework of the Interreg III-B European project called Sismovalp (Seismic hazard and alpine valley response analysis), a workpackage is devoted to the characterisation of "Alpine" valley configurations, by means of synthesis, acquisition and comparison of the geological and geotechnical parameters of some characteristic pilot alpine valleys.

These valleys are Grenoble Isère river valley (F), Valais Rhone valley (CH), Bovec basin, upper Soca valley (Slo), Tagliamento river high valley (I), Gemona del Friuli (I), Val Resia (I), Val Pellice (I) and Val d'Aosta (I). All of these regions benefit from recent scientific work, fast building expansion and local authorities interest, which help the achievement of the project.

The investigations conducted through the Sismovalp project include new geotechnical and geophysical studies necessary to characterise the pilot valleys. Information have been collected about the geological configuration and history of the valleys, including physical geography, geological and seismic history, available geotechnical and geophysical data, human activity (urbanisation, industrialisation), detailed geological description. A synthesis of all this information makes it possible to derive some generic alpine valley profiles as well as to build 2D models of some of the valleys. These profiles will be available on an open database.

During the project, an important work to validate and document the geophysical methods used to explore the pilot valleys has been carried out and will be disseminated freely to the seismic engineering community in order to improve the quality of microzonation studies.

1. INTRODUCTION

In the framework of the European Interreg III project called SISMOVALP (Seismic hazard and alpine valley response analysis), a work package was devoted to the investigation and characterisation of some alpine valleys. The approach used was to define criteria describing the valleys in sites where a lot of information is available. This information could then be transformed into generic data that could be used for the characterisation of other valleys for which the available data is poor. Some common generic criteria can be looked at, whereas some particularities characterise each individual valley. In the framework of the project, several in situ investigations where also conducted.

The eight following valleys, located in France, Slovenia, Switzerland and Italy, have been investigated in details in the framework of the SISMOVALP project :
- Grenoble Isère river valley (France)
- Valais (Switzerland)
- Upper Soca valley (Slovenia)

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- Tagliamento river high valley (Italy)
- Gemona del Friuli (Italy)
- Val Resia (Italy)
- Val Pellice (Italy)
- La Salle, Val d'Aosta (Italy)

2. INVESTIGATED CRITERIA

The main criteria searched for are geometrical and dimension criteria of the valley and criteria describing the sedimentary deposits filling the valley in a geometric, physical, mechanical and geotechnical sense.

2.1 Location, geometry and dimensions

Post glacial lakes location, in the Alps, is a major criteria for the characterisation of the valleys. Major present glacial lakes are often located at the maximum extension limit of the former glacier, in a place where deposits did not reach a complete filling of the glacial valley.

The transversal section of the valley can by symmetrical or asymmetrical, depending on the nature, the geometry and the topography of the bedrock. The shape of the valley is a result of the stiffness of the rock but also of the erosion duration. Generally, it is considered that "hard rocks" tend to produce "U" shaped valleys, whereas "softer rocks" are characterised by "V" shaped valleys. The valley may have been dug during successive glacial events. This can be seen with some lateral shoulders or over-digging shapes. These particular shapes can have some effects on the wave propagation into the valley (diffraction effects, basin edge, etc). The bottom of the valley can also be horizontal or irregular, depending mainly on the lithology and structure of the bedrock.

Glacial valleys usually have a regular general slope, due to the very slow but very strong action of the glacier. The nature and structure of the substratum can cause some local irregularities such as narrow sections (due to harder rocks) leading to an over-digging upstream.

The dimensions of the valleys are linked to the altitude and the geological context. The size of the basin feeding the river that drains the glacial valley contributes to the formation of a strong glacier. There is a link between the slope of the valley and its width : a strong slope is associated with a narrow section, whereas a gentle slope characterises a wide valley. This means that the slope and width of the valley are determined by the bedrock lithology.

2.2 Characterisation of the valley deposits

In general, valleys are characterised by a longitudinal sorting, based on a transition between coarse deposits at the upper part of the valley, close to the feeding basin, and downstream zones with fine lacustrine deposits, where the only coarse deposits are located on the sides, with limited extensions.

The vertical sorting is due to sedimentological rules and to local paleo-geographical criteria. In each valley, the vertical succession of the deposits should be the same, for the same depositional and sedimentological conditions, resulting of the evolution of the sedimentation process with time (glacial filling sequence → lacustrine sequence → fluvial sequence).

A lateral sorting is also caused by coarse material coming from lateral valleys, falling into the lake and then being mixed to the fine lacustrine sedimentation. These can cause shapes like canals, alluvial fans and slope deposits. They have generally a limited lateral extension in the basin.

Physical, mechanical and geotechnical properties of the valley deposits can be investigated by means of several techniques. In the valleys studied during the SISMOVALP project, the following type of investigation techniques have been used :
- boreholes,
- gravimetry,
- seismic reflection, refraction, SASW,
- ambient vibrations,

- electric surveys.

Some of the data have been acquired during the SISMOVALP project, some others, already existing, have been directly used.

3. SYNTHESIS OF THE CHARACTERISATION OF THE INVESTIGATED VALLEYS

A detailed questionnaire has been filled by the participants to the project for each valley. This questionnaire was aimed at gathering information about the geography, the geological and seismic history of the valley, the available geophysical data, the human activity, and the geological characterisation of the valley. Using all the information collected, a synthesis table has been prepared, as shown here in Table 1. This allows a comparison between the different valleys studied during the SISMOVALP project.

One aim of the synthesis was to see if it is possible to use all the available data in some valleys to draw some generic characterisation for other valleys where detailed information is missing. The valley classification can mainly be done regarding the extent : size, degree of maturation and evolution of the valley. Three categories can be proposed :

- Major valleys (Grenoble Isère F, Valais CH) which are exceptionally large. They are characterised by their length, the maximum thickness of the deposits (around 900 m). Their size is associated with the great number of smaller lateral valleys. The nature of the deposits is depending on the distance from the uppermost part of the valley. These valleys lead to very low frequency amplification, due to the thickness of the sedimentary deposits.
- Minor valleys are located at higher altitude and are directly connected to their direct water source. Their topography is quite high, they are usually narrow, rather short, with a steep slope and a meandering shape. The deposits are very coarse, with slope or torrential deposits. These valleys are generally characterised by amplification at higher frequencies.
- The last type is called intermediate valleys because of their intermediate dimensions. They are often occupied by glacial lakes and located at the limit of the glacier extent, between stiff and softer formations. These lakes correspond to an over-digging of the glacial valley. Depending on their local environment and their distance to the drainage basin, they are filled with coarse detrital material or fine sediments.

The use of all available existing data, as well as new data acquisition performed during the SISMOVALP project, made it possible to draw some 2D profiles across most of the studied valleys. These 2D profiles are given, in terms of a bedrock profile as well as an S-wave velocity structure, in a databank available on a CD-ROM, together with the detailed description of the valley, as mentioned above . These data can be used to adjust appropriate models for other valleys where detailed information might not be available.

Table 2: Synthesis of the characteristics of the investigated alpine valleys

VALLEY NAME	Grenoble Isère river valley	Lower Valais (Massongex - Aigle)	Bovec basin (upper Soca valley)	Tagliamento river high valley	Gemona del Friuli	Val Resia	Val Pellice	La Salle (Val d'Aosta)
COUNTRY	France	Switzerland	Slovenia	Italy	Italy	Italy	Italy	Italy
GEOGRAPHY								
Orientation	NNW - SSE	NNW - SSE	ENE - WSW	NW - SE	E - W	E - W	E - W	NE-SW
General shape	Basin Y shape	U shape	basin	U shape	Triangular alluvial fan	V shape	V shape	Triangular alluvial fan
Length	61 km	Total Rhône valley ~150 km, study area 7.5km	6 km	Total: 40Km, study area:7.5km	2.4 km	20 km	35 km	1.5 km
Main width	5 km	5 km	2 km	1.5 to 2 km	1.5 to 2.5 km	4 to 8 km	2 km	2 to 2.5 km
Thickness of quaternary deposits	few to 900 m	0 to 900 m	0 to 260 m	0 to 120m	max 100-150 m	5 to 50 m	10 to over 180 m (northern side)	max 200 m
Elevation above sea level	198 to 475 m	380 to 400 m	350 to 450 m	270 to 320 m	195 to 560 m	400 to 700 m	400 m to 1000 m (main towns)	850 to 1100 m
HISTORY								
General geological evolution	Riss : first glacial trough dug in the bedrock, glacier melting, lake, lacustrine sediments. Würm : second trough dug in the sediments, down to the bedrock, glacier melting, lake, lacustrine sediments, fluvial déposits.	Several glacial stages, alternating with lacustrine and fluvial environments with recent deltaic and slope deposits on the valley edges	Succession of glacial, lacustrine and fluvial environments during the Quaternary	Two main orogenic phases; intense tectonic activity; several glacial phases in Pleistocene age; today the valley is characterised by Tagliamento river and its tributaries, alluvial fans and tectonic terraces (high 100m to the plain)	Gemona alluvial fan has intermediate character between alluvial and detritic. Rockfalls have also contributed to its fomation on the flanks. Fan's surface post-glacial, alluvial deposits	Numerous glaciations, erosive processes alternatively due to glacial and fluvial actions. Today, most of the valley is characterized by alluvial terraces, several tens of meters high.	Lacustrine deposits at the bottom of the valley, with alternating fluvial sequences. Over are fluviatile and torretial deposits. To a lesser extent, some glacial deposits. Glacial effects have been very small in this valley.	During the Quaternary, succession of alluvial fan deposits, made up of medium to coarse grainsize, on deposits of glacial enviroment.
Past lake	YES	YES	YES	YES, marginal	NO	?	YES	NO
Over-digging (app. depth)	YES (720 m by Würmian glacier)	YES	NO	Probable	YES (5-10 m)	YES	NO	YES
Past glacier	YES (2 stages)	YES	YES	YES	YES	YES	YES	YES
Seismic activity (intensity, magnitude)	I=VI-VII (1754) ; I=VII-VIII (1822) ; I=VII-VIII, M=5.7 (1905) ; I=VII-VIII (1935) ; I=VII-VIII (1959) ; I=VII-VIII, M=5-5.3 (1962) ; I=VII-VIII, M=5-5.5 (1963, 1996)	Historical events in the Valais:Mw=6.4, Imax=8 (1524); Mw=6.1, Imax=7 (1685); Mw=6.1, Imax=8 (1755); Mw=6.4, Imax=8 (1855); Mw=6.1, Imax=8 (1946); Mw=6.0, Imax=7 (1946)	IMSC=10, M=6.9 (1511) ; IEMS=7-8, ML=5.6 (1998)	Epicenter in study area ONLY: 1788, I=VIII,1794, I=IX, 1908, I=VII-VIII, 1928, I=VIII-IX, 1959, I=VIII, more than 1000 earthquakes recorded by RSFVG; MD=4.2(1988), MD=4.9(2002)	I=VII (1389) ; I=IX (1511) ; I=VII (1908) ; I=X, ML=6.4 (1976)	I=VIII, M=6.4 (1976) at 10km ; M=5.7 (1998) at 20km ; M=6.9 (1511) at 50km	Max I-MCS=VIII	Max I-MCS= V
DATA								
Boreholes	2000 + 1 deep	YES	YES	59 – all shallow (<30m)	YES	YES	already available: 31 boreholes and wells stratigraphies; obtained within Sismovalp Project: 4 boreholes	5 pre-existing boreholes (SPT Tests) + 2 new boreholes (Downhole Tests) not yet available
Gravimetry	419 measurments	YES	NO	300 measurements	YES	YES	already available: 4 gravimetric electric sections	NO

VALLEY NAME	Grenoble Isère river valley	Lower Valais (Massongex - Aigle)	Bovec basin (upper Soca valley)	Tagliamento river high valley	Gemona del Friuli	Val Resia	Val Pellice	La Salle (Val d'Aosta)
COUNTRY	France	Switzerland	Slovenia	Italy	Italy	Italy	Italy	Italy
HUMAN ACTIVITY								
Urbanization	12145 km2 urbanized	YES	One town 3350 inhabitants, Upper valley : 20000 (2 to 3 times during touristic season)	Two towns: Tolmezzo, 10600 inhabitants and Cavazzo Carnico, 1100 inhabitants	about 15000 inhabitants	< 1400 inhabitants concentrated in 4 small villages	about 10% of the surface, Torre Pellice town nearly 5000 inhabitants	<1800 inhabitants
Industry	YES (very important)	YES (Refining, chemical)	YES	YES	NO	NO	YES, marginal; in particular, main industrial activities connected with “Pietra di Luserna” extraction and processing and disused textile industrial activities;	not relevant
GEOLOGY								
Bedrock type	Limestone	Limestone, Molasse, Flysch, Conglomerate and Gypsum	Platform carbonates	Dolimites and Limestones	Dolomites	Mainly dolomites, some limestones, few evaporites	Micaschiste, gneiss, schiste, prasinite, amphibolite, serpentinite, calcschiste	Micaschistes, gneiss, amphibolites and generally high-grade metamorphic rocks.
Bedrock slope (sides)	15° to 19°	15° to 50°	30° to 50°	Steep to sub-vertical	30° to 35°	40° to 50°	7° to 60°	10° to 50°
Bedrock outcrop inside the valley	NO	YES	YES	NO	YES	YES	YES	NO
Type of quaternary deposits	Alluvial (sand and gravels, lenses of silt, sands and clay) ; Lacustrine (fine sands, clayey sands or silts) ; Torrential (compact clays) ; Morainic (rock or stones in clayey matrix, or heterogeneous linear deposits)	Alluvial , Lacustrine, Torrential, Morainic, Deltaic	Alluvial (gravel, sandy gravel, sand), Lacustrine (chalk), Torrential (gravel), Morainic (till, tillite), Slope scree, diamiktit, diamikton (mass mouvement deposits)	Alluvial (gravel, cobblestone, sandy gravel, sand), Lacustrine (fine sands and silts), Torrential (fan deposits), Morainic, Landslide deposits	Alluvial (gravel, sands, silty-clay matrix with pebbles and gravels)	Alluvial (gravels), Lacustrine (silt and clay), Torrential (pebbles, screes), Morainic (pebbles, sands and clay), conglomerates	Alluvial (gravels and sand) , Lacustrine (silts, clays), Torrential and fluviatile (sandy gravels with pebbles), Morainic (very rare traces in the upper valley only)	Alluvial conoid deposits(sand, gravel,stone).Polygenic slivers, stones and blocks (3-4 cm to meter scale)
General dip direction of deposits	Horizontal	1.14° (2%) towards NNW	towards ESE	SE	towards SW	gently towards W	gently towards E	gently towards SW
Mud flow channel	YES	YES	YES	NO	NO	NO	NO	NO
Fan delta	NO	YES	YES	YES	YES	NO	YES	YES
Lacustrine delta	YES	YES	YES	NO (but locally outcrop lacustrine deposits)	NO	NO	YES	NO
Marsh / peat bog	YES	YES	NO	NO	NO	NO	NO	NO
Collapse zone	YES	YES	NO (probabale)	NO	NO	NO	YES	YES
Landslide, creeping	YES	YES	NO (possible)	YES	NO	NO	YES	YES
Rockfall activity	YES	YES	YES	YES	YES	YES	YES	YES
Scree deposits on sides	YES	YES	YES	YES	YES	YES	YES	YES
Lateral water streams, torrent, valley	NO	YES	YES	YES	YES	YES	YES	YES
artificial fills	NO	YES (Tips)	NO	YES (very limited)	NO	NO	NO	NO
Others		Dolines				some erratic rocks	About shape: double palaeo-bedriver (V-shape). Some erratic rocks in the upper valley.	

4. GENERIC APLINE VALLEY FOR A MODELLING BENCHMARK

At the beginning of the SISMOVALP project, all available information from the valley configurations have been collected in order to propose a generic model for a simulation benchmark. The realistic generic model chosen for these simulations is presented on Figure 1.

The internal structure of the valley has been defined by a 1D model. The benchmark considers three 1D models (presented in Table 2). The reference model is a layered model (M0), made by non-saturated sediments. The second model (M1) is the same as M0, but it features a water saturated layer. The third model (M2) displays a smooth velocity variation, with no internal interfaces. The physical parameters depend on depth, with an explicit analytic formula.

The model proposed for the benchmark is a generic model representative for an intermediate to major sized alpine valley, with 450 m of sediments (like for example the intermediate part of the Valais). 2D computations where performed using different simulation frames, in order to compare the results obtained. The benchmark and associated results, carried out in the framework of another workpackage of SISMOVALP, are not described in the present paper.

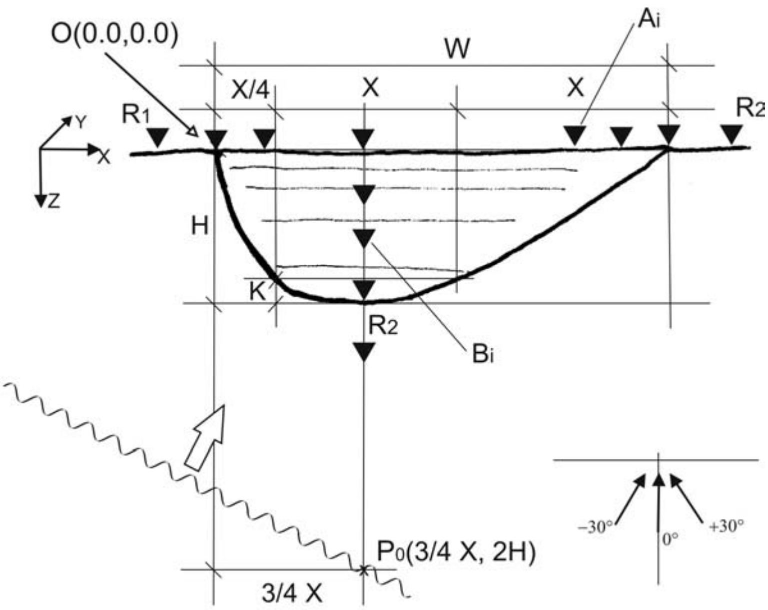

Figure 1: Geometry proposed for a generic valley configuration

Table 2: Description of the three 1D models proposed for the internal structure of the alpine valleys. Model 0: reference model; Model 1: same as model 0, but with Vp/Vs increased in the water saturated layer; Model 2: similar to model 0, but with smooth increase of velocity with depth

Model 0 (M0)								
Stratigraphic layout	**Units**	**H (m)**	**V_S (m/s)**	**Vp (m/s)**	**V_P/V_S**	**ρ (kg/m³)**	**Q_S**	**Qp**
Recent Deposits	Sandy Gravel	0-15	250	500	2.5	1600	20	40
Fine Deposits	Silt & clay	15-30	350	700	2.5	1700	20	40
Fluvial & Lacustrine Deposits	Silt, clay and gravel	30-100	450	900	2.5	1800	30	50
Fluvial & Lacustrine Deposits	Silt, clay and gravel	100-350	600	1200	2.5	1900	30	50
Moraine	=	350-450	800	1600	2	2000	50	100
Bedrock	Limestone	450-∞	2800	5200	1.85	2500	200	400

Model 1 (M1)								
Stratigraphic layout	**Units**	**H (m)**	**V_S (m/s)**	**Vp (m/s)**	**V_P/V_S**	**ρ (kg/m^3)**	**Q_S**	**Qp**
Recent Deposits	Sandy Gravel	0-15	250	500	2.5	1600	20	40
Fine Deposits	Saturated Silt & clay	15-30	350	1650	4.7	1700	20	40
Fluvial & Lacustrine Deposits	Silt, clay and gravel	30-100	450	900	2.5	1800	30	50
Fluvial & Lacustrine Deposits	Silt, clay and gravel	100-350	600	1200	2.5	1900	30	50
Moraine	=	350-450	800	1600	2	2000	50	100
Bedrock	Limestone	450-∞	2800	5200	1.85	2500	200	400

Model 2 (M2)								
Stratigraphic layout	**Units**	**H (m)**	**V_S (m/s)**	**Vp (m/s)**	**V_P/V_S**	**ρ (kg/m^3)**	**Q_S**	**Qp**
Fluvial & Lacustrine Deposits	Silt, clay and gravel	0-450	$260 + 30\sqrt{z}$	$525 + 60\sqrt{z}$	≅ 2	$1600 + 59.5\ z^{1/3}$	$20 + 1.64\sqrt{z}$	$40 + 3.3\sqrt{z}$
Bedrock	Limestone	450-∞	2800	5200	1.85	2500	200	400

5. CONCLUSIONS

The work conducted through the "generic alpine valley configurations" workpackage of the SISMOVLP project made it possible to gather detailed information about eight alpine valleys. Existing data as well as new data acquisition campaigns have been used to answer a detailed questionnaire about the geography, history, geology of the valleys.

A synthesis makes it possible to compare and classify the valleys and to draw some common features that can be investigated for other similar valleys. A CD-ROM has been prepared, containing all the information about the valleys. Furthermore, where collected data was sufficient, some 2D profiles have been drawn across the valleys. These profiles, included into the CD-ROM, give for each section, the bedrock topography and an associated S-wave velocity structure. These data can therefore be used to adjust appropriate models for other valleys where detailed information might not be available.

Finally the information about real valleys has be used to derive a generic alpine valley profile that has been used to perform a 2D benchmark, using several site effect modelling approaches.

6. ACKNOWLEDGMENTS

This work was financed by the European Interreg IIIB Alpine Space project SISMOVALP, number F/1-2/3.3/25. We are very grateful to all participants into the WP04 and WP06 SISMOVALP worpakages, for continuous very good collaboration.

7. REFERENCES

A detailed reference list, for all the investigated valleys will be given on the CD-ROM of the SISMOVALP project. SISMOVALP web-site : http://www-lgit.obs.ujf-grenoble.fr/sismovalp

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