A new scale for avalanche intensity

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Abstract: After different natural disasters occurred in France these last years, French Ministry of Environment wanted to build new scales about of natural phenomena intensity such as volcanic eruption, flooding, forest's fires, atmospheric phenomena (wind, hail storm, ...) and avalanches. The goal is to better qualify each event after it's coming. The main criteria are :

- a few physical parameters on the phenomenon itself,
- the effective or possible damages on people, buildings, substructures, natural area,
- others criteria.

Each scale has from 4 to 6 levels with a coordinate description. They are independent from the site vulnerability. Non specialists of the phenomenon can understand or use them very often. For one event, usually all the describe parameters are not on the same line level : the choice can be made with the strongest.

The avalanche scale has got 5 degrees, from 1, very low, to 5, exceptional. The physical parameters are surface area, depth of the starting snow, volume of the snow deposit, impact pressure. Human beings are distinguished between observant and carrying along. The effects on the different building parts (openings, wall, roof) are mentioned. The many possibilities for road (vehicle, damages, burying) and for tree and forest are detailed. This new scale uses also the possible noise or unexpected path., and the effects on engineering works for avalanche protection.

Keywords: avalanche classification, avalanche types, avalanche intensity, avalanche accidents

1 Introduction

During year 2001, the French ministry of Environment financed a study for the determination of new intensity scales for various types of natural hazards: dependent on the atmosphere (wind storm, tornado, cyclone, hail storm, icing rain, snow, lightning), floodings, torrents flows, avalanches, movements of ground, seisms, tsunamis, volcanic eruptions, and forest fires.

The goal was to compare several events concerned by the same risk as to provide a common framework between these various natural risks. Regarding a country like France, the "exceptional" character of the event is better relativized. Finally, the description of damages also allows a comparison with subsequent costs of protection.

The principal technical conditions imposed by the contract were:

- the scales to be created have only a role of report: they are not used to establish by advance a level of vulnerability or hazard,
- the scales must be comprehensible and usable for all users: except justified exception, the criteria of description are easily accessible,
- each scale must make it possible to qualify the effects of each event, then to compare several events between them: the criteria of description must be diversified especially on the damage,
- the scales must be able to be usable for last events: the criteria of description should not be too complex, "scientific" measurement should not be essential.

This article treats then only snow Avalanches risk.

2 Definition

The avalanche is a fast gravitating displacement of a significant volume of snow on an inclined ground [1].

The movement is gravitating: the gravity reveals it and acts primarily on the phenomenon. This distinguishes it from the wind transported snow. In the avalanche, the potential energy of the snow deposited in altitude is transformed into kinetic energy.

The movement is fast: speed is counted in meters per second. This distinguishes it from the snow gliding which moves in centimetres per hour.

Volume is "significant": at least some tens cubic meters, often thousands. This certainly indicates a lower limit "vague", to avoid the simple snow "ball".

The movement naturally evolves on a ground, which can eventually be covered with snow. This characteristic

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thus excludes the snow fall from a tree (from its branches), snow glide from a roof, a springboard, etc. These snow movements can however constitute a real risk, for pedestrians, for cars.

The slope is necessary, at least at the beginning, to reveal the gravitating action. Nevertheless, under certain conditions, an avalanche can go through a plane area or even a counterslope.
Most of the time, its total difference in height is counted in hundreds of meters.

The avalanche can be apprehended [2] according to three interdependent concepts:
- as an event: it is characterized by the journalist with a place, a date and often with the main damages,
- as a physical phenomenon: it is studied by the scientist with characteristic values (geometrical, speed, density...) according to its type (flowing, powder/ aerosol...),
- as a risk: it is defined by the expert with a frequency and an intensity according to the place.

The proposed scale gives a part of response for each concept/ audience.

3 Existing classifications

3.1 Morphological classification

Avalanche moves in a site where three zones are distinguished:
- starting zone: from which the avalanche can occur, where snow accumulated beforehand, where the mass of moving snow increases,

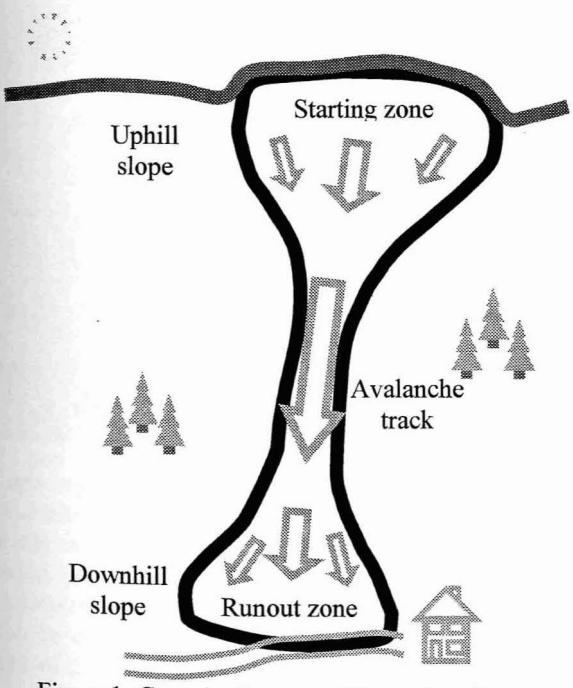


Figure 1: Generic diagram of the avalanche zones

- flowing track: on which the avalanche forwards,
- runout zone: on which the avalanche stops and settles, where the mass of moving snow decreases.

An international classification UNESCO was elaborated during the Seventies. It has not modified any more since 1981 [3]. It is very descriptive, morphological, and do not mention the possible intensity, nor the consequences, damages, of the phenomenon.

3.2 Dynamic classification

The avalanches are distinguished according to the interface position where the preponderance of dynamic friction is carried out:
- inferior (between the snow avalanche and "ground" or snow-cover remaining): flowing avalanche;
- superior (between the avalanche and the air): avalanche with aerosol/ powder snow avalanche; significant cloud is being developed at the avalanche head.

The dynamic friction may be relatively balanced between lower and superior friction: avalanche with back power cloud; small cloud is being developed behind the flow head.

The snow entrainment, or not, on the ground also constitutes an essential dynamic factor.

3.3 European meteorological avalanche scale

This scale relates the stability of the snow cover and the probability of its release [4]. It gives an index of risk in 5 levels. It was conceived in Europe at the beginning of the years 1990 for people practising the mountain out of the marked and opened ski slopes.

3.4 Existing intensity avalanche scales

The goal is to give some characters for a better distinguish of the width of the "avalanche" phenomenon, envisaged or observed. "Means" are developed (ex: impact pressures) with sometimes some specific "results" (ex: damages). The intensity of an avalanche is not evaluated (simply) only by the number of victims or destroyed dwellings. Using the word "magnitude" needs to measure a special physical characteristic.

3.4.1 American scale

In the USA since 1976 [5], the size of the avalanches is organized in 5 levels, primarily (except size 1) starting from a qualifier relative to the path. This is thus rather subjective and does not allow true comparisons between an avalanche witch occurs in one path to another.

3.4.2 Canadian scale

The main intensity scale existing before abroad is the one published in 1993 in « The avalanche Handbook » [6]. The classification is in 5 levels. It was established from:

- descriptive criteria referring to damages, on people, possessions (vehicles, buildings) or forest,
- "typical" values as mass, flow length and impact pressure.

But it is rudimentary about damages. Nevertheless, on this base, a scale was developed (not published) in France, in the year 2000, mainly centred on physical parameters. This new proposal is clearly in harmony with those two scales (Canadian and French) concerning the levels number for example, but with more details (ex: typical damages).

3.4.3 Swiss classification

It is mainly a list of correlation between values and sometimes ranges of impact pressures with potential damages. It has been primarily elaborated by a Swiss engineer, recently (2000) and not yet published, in my knowledge [7].

The avalanche type is well indicated, as the different damages. But there is no real scale.

Table **1** : Swiss classification according to impact pressures and potential damages.

Impact pressure (kPa)	Avalanche type	Potential damages
1-3	Powder snow/ Aerosol	Destroys a lonely tree (without forest protection)
1-4		Breaks the windows
>5-10		Destroys the forest
3-6	Dense snow	Pushes the gates, brooks/ crushes walls, roofs
3		Turnaround of a freight car (18 t)
8.5		Turnaround of a locomotive (120 t)
10		Serious damage of timber structures
20-30		Destroys timber structures, breaks the trees
50-100		Destroys a well developed forest
100		Pulling out large fir trees
>300		Movement of large blocks
1000		Movement of the reinforced concrete structures

4 The new intensity scale

4.1 Conditions

This new intensity scale applies to any snow avalanche involving damages. In the main cases, it is the impact of the fluid which produces damages. But the simple burying prolonged several minutes can cause the death of people.

The development of this scale was made on this preexistent basis, by developing the description of the possible damages, starting from the analysis of the events which have occurred in France, in particular the avalanches of Chamonix-Montroc and Chamonix-Taconnaz (1999), of Lauzet Peak (1998) and some others less known (ex: Lanches in 1995). Various documents and reports of mission were consulted as feedback experience. Then a consultation of several different experts was carried out in order to better determine the criteria as well as the scale thresholds.

The purpose of its use is to classify an event according to its intensity compared to others known in the past, using HAZUS scale model. Details much be given for different cases: people, buildings, infrastructure and works, natural and agricultural spaces, and others criteria.. we have added physical parameters with affected surface, average slab thickness, deposit volume and impact pressure.

4.2 Using the table

This new scale is showed in the 2 following tables (cause of paper formatting), linked in fact.

Each observer fills only one form according to its personal appreciations. Except justified exception, the final choice of the degree of intensity is made by retaining the level corresponding to the maximum observed and indicated about physical parameters, buildings and infrastructures. The criteria "People", "Natural and agricultural spaces" and "Others criteria" must be taken cared at a lower level than the others, not alone to classify.

The classification is carried out on the basis of information filled on the standard form of scale, according to visual inspection of various observers. The strongest observed effect must be significant.

In reference, special photos of different damages can helped (see paragraph 5).

Table 2 : Intensity scale for the avalanche risk (part 1). Version n°6 (August 2002)

Degree	Physical parameters (order of magnitude)	Foreseeable effects on the stakes (part 1)	
		People *	Buildings
1 Very low	Affected surface: ~ 0,2 ha Average slab thickness: ~ 20 cm Deposited volume: ~ 100 m^3 Impact pressure: ~ 2 kPa	Observer staying cool (except if somebody is carried along). Person carried along: - possible state of shock: momentary psychological disorder, - Light injury (requiring only basic medical cares without hospitalisation), - extremely rare death (except if the head is buried and if intervention time is over 15 minutes).	Generally no damages. Light structural damage: - furniture: damaged, - opening: pushed door, broken pane of window. Partial and very localised burying.
2 Low	Affected surface : ~ 1,0 ha Average slab thickness : ~ 40 cm Deposited volume : ~ 1 000 m^3 Impact pressure : ~ 10 kPa	Calm observer but "being on the alert" (except if somebody is carried along). Person carried along: - frequent state of shock: temporary psychological distress which can be prolonged, nervous breakdown possible, - frequent slight injury, but usually without after-effects nor disability, - serious injury (requiring thorough/ intensive care with a hospitalisation: traumatism, hypothermia.), - possible death as the flow stops.	Low structural damage: - opening (doors, windows, shutters): often unusable, - balcony: damaged, - masonry wall: fissuring and possible partial collapse, - roof: partial crushing, torn off edge, ploughed up chimney. Buildings touched: partial burying and/ or destruction of a few.
3 Medium	Affected surface : ~ 5 ha Average slab thickness : ~ 80 cm Deposited volume : ~ 10 000 m^3 Impact pressure : ~ 50 kPa	Agitated observer starting to fear for himself. Person carried along: - systematic state of shock: strong psychological disorder, nervous breakdown possible, - frequent serious injury, with possibility of after-effects or disablement, - frequent death.	Moderate structural damage: - opening: destroyed, - walls: fissuring, deformation, possible collapse, - roof: general crushing, or partial transport. Buildings touched: destruction of the majority. Destruction of old dwellings.
4 High	Affected surface : ~ 20 ha Average slab thickness : ~ 150 cm Deposited Volume : ~ 80 000 m^3 Impact pressure : ~ 200 kPa	Nearby observer which can panic. Person carried along: - almost systematic serious injury, - rapid and very frequent death.	Significant structural damage: -walls: levelling (possible by level of construction), multiple collapses, - roof: destruction. Buildings touched: Almost total destruction. Often total burying.
5 Very high	Affected surface : ~ 50 ha Average slab thickness: ~ 250 cm Deposited Volume: ≥~ 400 000 m^3 Impact pressure: ~ 500 kPa	Observer panicking. Person carried along: - almost systematic fatal injury, - instantaneous death.	Total structural damage, generalized ruin: - walls: levelling, systematic collapses, - particularly reinforced concrete structures: fissuring /at least partial destruction.

* : non relevant criterion in its number

Warning: These values, these possible "typical" qualifications have only for ambition to give an order of magnitude, a relevant unit of measurement for the concerned parameter, a suitable reference. Others parameters exist but are not taken into account (ex: characteristics of the mobilized snow, extent of the starting zone, topography, variations according to vertical fall distance, width and length of the flow, type of flow, etc). Thus the qualifications selected can be enough different for a particular avalanche: inevitably, they are not always coherent according to the same line of this table: it is then necessary to choose the degree according to parameters' which appear most representative.

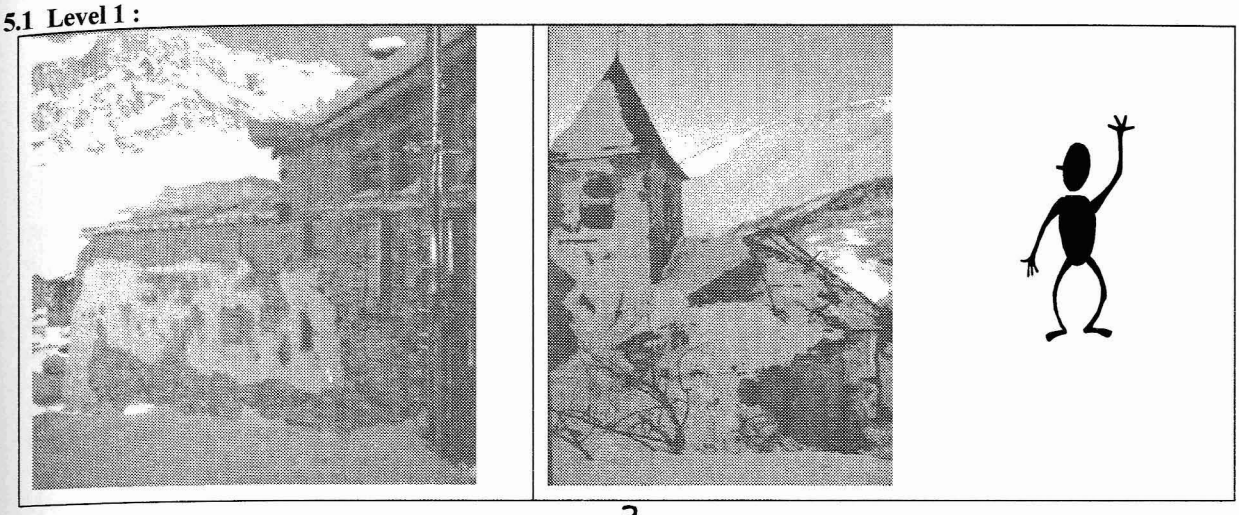
Table **3** : Intensity scale for the avalanche risk (part 2). Version 6 (August 2002)

Degree	Foreseeable effects on the stakes (part 2)		Other criteria
	Infrastructures and works	**Natural and agricultural spaces**	
1 **Very low**	No damages. Road locally and temporarily slippery and blocked, but which can still be used by a well-equipped 4x4 vehicle.	Broken branches of tree.	-
2 **Low**	Low damage: - wood/ lattice post, line: partial destruction, - cars, bus: turned around (and buried). Road can turn out to be locally and temporarily impracticable (even for a equipped 4x4 vehicle): loss of the layout under the deposit, necessity of clearing.	Broken trees, insulated or in groups.	Perception of the sound from the flow: possible.
3 **Medium**	Moderate damage: - crash barrier, concrete/ steel post: generalized destruction, - loaded truck, freight car: turnaround (and burying). Impracticable road: loss of the layout, necessity of extensive clearing work.	Locally broken mature forest: transport of trees. Pulling out and transport of stones/ blocks. Possible obstruction of waterways by the snow deposit.	Perception of the sound from the flow: frequent. Effect of blast: possible. Avalanche inside many others: possible.
4 **High**	Significant damage: - superstructure not especially adapted and forming obstacle: generalized destruction, - locomotive: possible turnaround. Total cover and/or damage over a significant length of roadway. Engineering avalanche works: - possible partial overflow, - possible partial destruction.	Destruction of about ten hectares of forest. Pulling out and transport of rocks bigger than 1 m^3. Generation of a wave in a lake. Notorious temporary modification of local topography (deposit of snow). Possible formation of a dam and a lake.	Eccentric/ rare trajectory: possible. Avalanche inside many others: frequent. Temporary control measures (evacuation or restrictions): possible.
5 **Very high**	Very significant and generalized damage. Engineering avalanche works: - possible repeated and/or extended overflow, - possible frequent and/or extended destruction.	Very wide destruction of any shrubby vegetation. Landscape radically transformed by this destruction. Strong accumulation of transported things.	Eccentric/ rare trajectory: extended/ frequent. Temporary control measures (evacuation or restrictions): generalized.

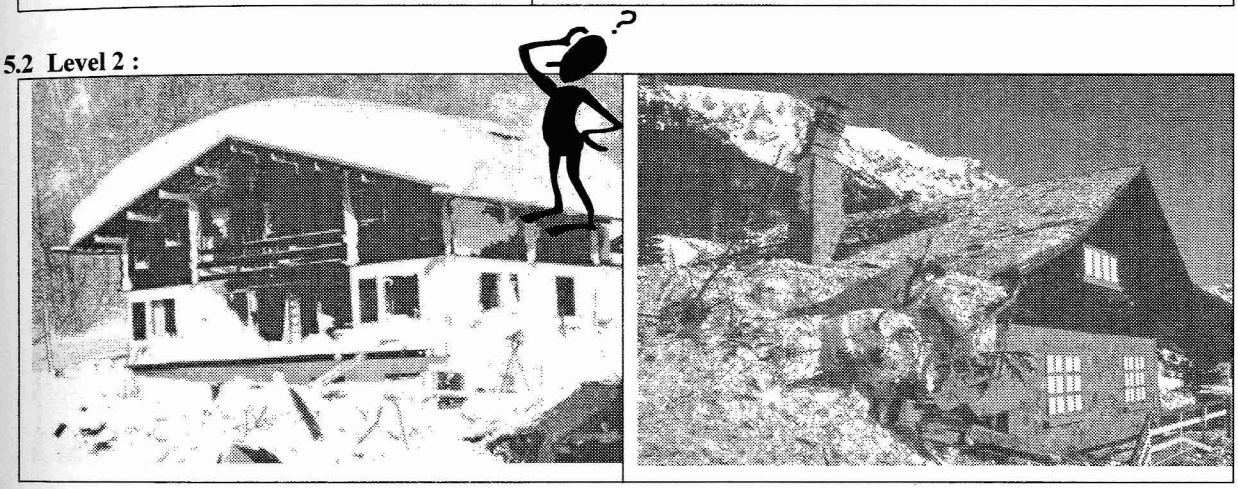
Warning: see page before

5 Graphic documents for assistance to the qualification of the intensity level reached

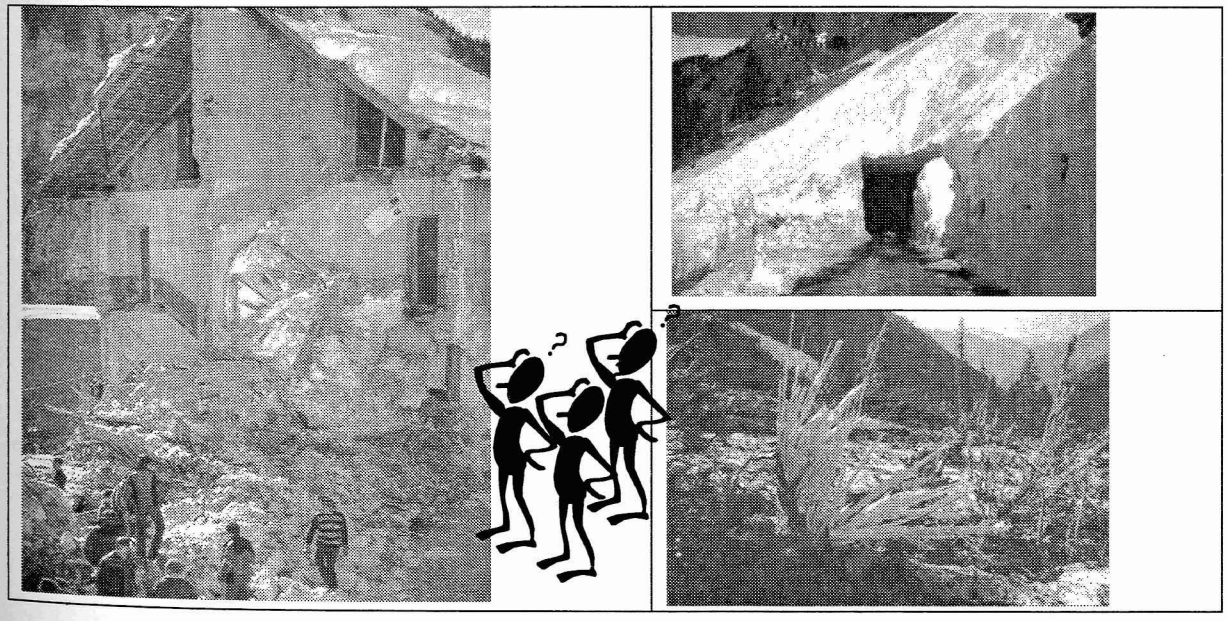
5.1 Level 1 :



5.2 Level 2 :



5.3 Level 3:



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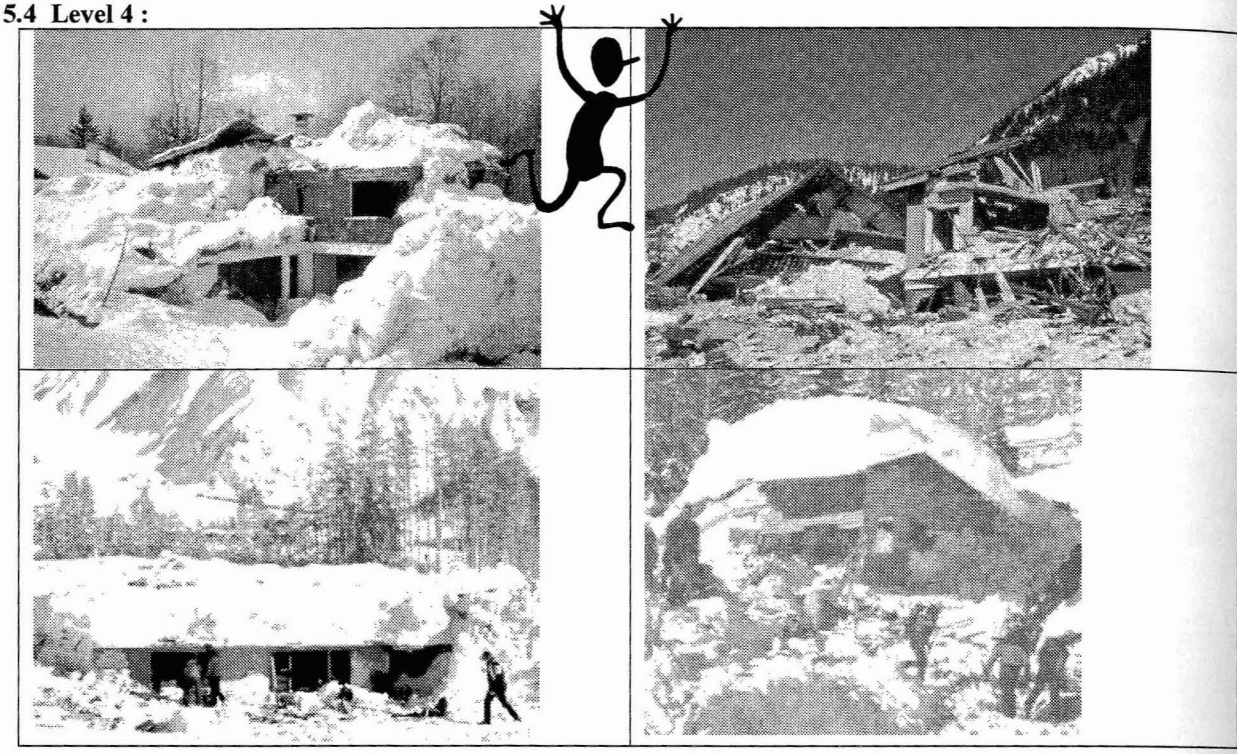
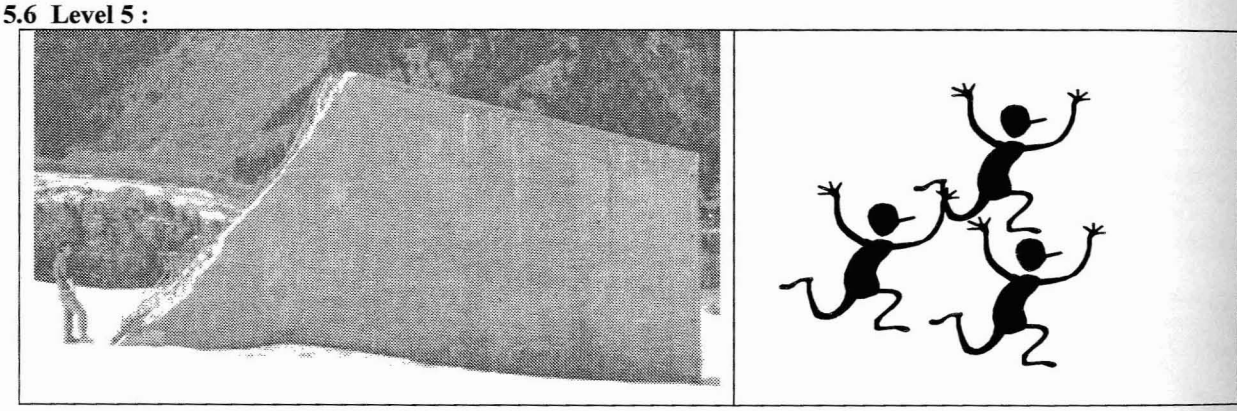


5.6 Level 5 :



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