SCALE OF SEISMIC INTENSITY

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SYNOPSIS

In describing the damage of buildings and structures from earthquakes, the scale provides the following subdivisions: first, by the types of buildings and structures; secondly , by the degree of damage of buildings; thirdly, by the number of buildings damaged during an earthquake. The text is presented of the scale of seismic intensity, suggested by the authors.

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The description of the effects of the quake is differentiated in the seismic scale MSK-64 in three directions; 1. the perceptibility by human beings and surroundings; 2. buildings of any type; 3. effects in the underground and alterations of the groundwater and superterrestrial water systems.

Such a structure differs the MSK-64 from all the other scales. The separated description makes it possible to watch the increase of the effect, on the basis of one single sign, with the increase of the intensity of earthquake, which allows a better valuation of an effect observed. In the other scales the same signs are used for the characteristic of an earthquake. As, however, a separated description does not exist the finding out of the characteristic earthquake effect of any degree in connexion with the neighbouring degrees becomes complicated.

It must be admitted that in the given scale as well as in the other scales the use of several signs may theoretically lead to a divergence between the signs for the single characteristics.It can be said that no difficulties of that kind occured in practical experience. But should once such a divergence occur, then those signs are to be preferred which have as a basis the descriptions of damages to buildings, because the assessment of these damages is the main objective of the scale. The signs will be most accurate, if the damages

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are exactly analysed and the peculiarities of construction and the measurements of the building, their state, the conditions of the underground are taken into consideration. The permanent effects in the underground as well as the alteration of the ground-water level do not allow the exact determination of the intensity of the earthquake. The immediate perceptibility of earthquakes by human beings is subjective, therefore, it cannot be regarded as a true characteristic of the intensity of the vibrations. But for the lower degrees of the scale, however, it can be hardly done without it.

The description of the damages to buildings by earthquake is subdivided in the scale in contrast to other scales, first according to the types of buildings, secondly according to the degree of damages to buildings and thirdly according to the number of buildings damaged by an earthquake.

The division of the buildings according to types was made in consideration of the different stability of the buildings against seismic actions. The buildings have been arranged in an ascending order and in accordance with security against quakes in the groups A, B and C.

The classification of damages to buildings provides five categories: slight damages, moderate damages, considerable damages, destructions and collapses. The designation of each category characterizes its content. Nevertheless, for the sake of greater distinctness short descriptions of each category have been given in the scale.

In respect of the number of the damaged buildings the scale gives a subdivision as follows: most, many, single; in addition to that a relation in per cents for orientation. These determinations are to be regarded in relation to the total amount of buildings of a group given. Within a group the buildings are not homogeneous concernong their structural peculiarities, building material, and in the state of condition, wherefore the percental part of the damaged building can characterise the intensity of the earthquake.

The data for ground investigations in the case of larger earthquakes show that the movement is complicated and irregular. The determinations of the vibrations of the underground of buildings only with tne help of maximum acceleration without giving the period of vibration, as e.g. in the Mercalli-Cancani-Sieberg-scale, is not Sufficient. The velocity of vibration, with regard to the periods, is in a series of cases obviously representative

for the seismic effect on buildings.

The quantitative determinations of the intensity of vibrations on land surface can be carried out according to one of the following methods:

a. The determination of the vibration spectra of the underground in Fourier form with the three components, by means of mechanical or semiautomatic decomposition into the Fourier-line of the records received.

b. The determination of the spectra of quasi-periodical vibratiobs. Here the period is understood to be double the time-interval between two neighbouring zero-values of a measured figure, and the amplitude is the extreme value corresponding to this period.

c. The determination of the energy current density in the case of seismic ground movements at the observation point.

d. Representation of the spectra of the effect of seismic vibrations on buildings. The effective spectra represent the dependency of the maximum amplitudes of pendulums with different periods and equal logarithmic damping decrements on the ground movement. Effective spectra can likewise be expressed as diagrams of the maximum velocities or maximum accelerations of vibrations of pendulum systems.

When making up the MSK-64 scale of seismic intensity the following purposes were kept in mind:

1. Fixation of the degree of the intensity of an earthquake as unexceptionable as possible.

2. Renewed determination of the intensity of all the earthquakes which took place in the past on the basis of data given in literature and of other information. This is by way of example necessary for a unitary judgment of the seismicity and seismic zoning.

3. The relationship between the macroseismic effect and the quantitative characteristics of intensity is to be established. This is necessary for the further development where the application of instrumental measurements of intensity is taken into consideration.

4. The macroseismic effect is to be characterized for the development of antiseismic building.

5. The purpose of the scale is to serve for the estimate of shocks expected on the land surface to solve the tasks set for the prediction of earthquakes.

SEISMIC INTENSITY SCALE VERSION MSK 1964

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Classification of the Scale

I Types of Structures (buildings not antiseismic)

Structure A: Buildings in field-stone, rural structures, adobe houses, clay houses

B: Ordinary brick buildings, buildings of the large block and prefabricated type, half timbered structures, buildings in natural hewn stone.

C: Reinforced buildings, well-built wooden structures.

II Definition of quantity

Single, few : about 5%

Many : about 50%

Most : about 75%

III Classification of damage to buildings

Grade 1 : Slight damage: Fine cracks in plaster; fall of small pieces of plaster

Grade 2 : Moderate damage : Small cracks in walls; fall of fairly large pieces of plaster; pantiles slip off; cracks in chimneys; parts of chimneys fall down

Grade 3 : Heavy damage : Large and deep cracks in walls; fall of chimneys

Grade 4 : Destruction : Gaps in walls; parts of buildings may collapse; separate parts of the building lose their cohesion; inner walls and filled-in walls of the frame collapse

Grade 5 : Total damage : Total collapse of buildings

IY Arrangement of the Scale

a) Persons and surroundings
b) Structures of all kinds
c) Nature

Intensity

I Not noticeable

a) The intensity of the vibration is below the limit of sensibility; the tremor is detected and recorded by seismographs only

II Scarcely noticeable (very slight)

a) Vibration is felt only by individual people at rest in houses, especially on upper floors of buildings

III Weak, partially observed only

a) The earthquake is felt indoors by a few people, outdoors only in favourable circumstances. The vibration is like that due to the passing of a light truck. Attentive observers notice a slight swinging of hanging objects, some-what more heavily on upper floors

IY Largely observed

a) The earthquake is felt indoors by many people, outdoors by few. Here and there people awake, but no one is frightened. The vibration is like that due to the passing of a heavily loaded truck. Windows, doors and dishes rattle. Floors and walls creak. Furniture begins to shake. Hanging objects swing slightly. Liquids in open vessels are slightly disturbed. In standing motor cars the shock is noticeable

Y Awakening

a) The earthquake is felt indoors by all, outdoors by many. Many sleeping people awake. A few run outdoors. Animals become uneasy. Buildings tremble throughout. Hanging objects swing considerably. Pictures knock against walls or swing out of place. Occasionally pendulum clocks stop. Few

unstable objects may be overturned or shifted. Open doors and windows are thrust open and slam back again. Liquids spill in small amounts from well-filled open containers. The sensation of vibration is like that due to a heavy object falling inside the building

b) Slight damages of grade 1 in buildings of type A are possible

c) Sometimes change in flow of springs

YI Frightening

a) Felt by most indoors and outdoors. Many people in buildings are frightened and run outdoors. A few persons lose their balance. Domestic animals run out of their stalls. In few instances dishes and glassware may break, books fall down. Heavy furniture may possibly move and small steeple bells may ring

b) Damage of grade 1 is sustained in single buildings of type B and in many of type A. Damage in few buildings of type A is of grade 2.

c) In few cases cracks up to widths of 1 cm possible in wet ground; in mountains occasional land-slips; change in flow of springs and in level of well-water are observed

YII Damage to buildings

a) Most people are frightened and run outdoors. Many find it difficult to stand. The vibration is noticed by persons driving motor cars. Large bells ring

b) In many buildings of type C damage of grade 1 is caused; in many buildings of type B damage is of grade 2. Many buildings of type A suffer damage of grade 3, few of grade 4. In single instances landslips of roadway on steep slopes; cracks in roads; seams of pipelines damaged; cracks in stone walls.

c) Waves are formed on water, and water is made turbid by mud stirred up. Water levels in wells change, and the flow of

springs changes. In few cases dry springs have their flow restored and existing springs stop flowing. In isolated instances parts of sandy or gravelly banks slip off.

YIII Destructions of buildings

a) Fright and panic; also persons driving motor cars are disturbed. Here and there branches of trees bresk off. Even heavy furniture moves and partly overturnes. Hanging lamps are in part damaged.

b) Many buildings of type C suffer damage of grade 2, few of grade 3. Many buildings of type B suffer damage of grade 3 and few of grade 4, and many buildings of type A suffer damage of grade 4 and few of grade 5. Occasional breakage of pipe seams. Memorials and monuments move and twist. Tombstones overturn. Stone walls collapse.

c) Small land-slips in hollows and on banked roads on steep slopes; cracks in ground up to widths of several centimeters. Water in lakes becomes turbid. Dry wells refill and existing wells become dry. In many cases change in flow and level of water.

IX General damage to buildings

a) General panic; considerable damage to furniture. Animals run to and fro in confusion and cry.

b) Many buildings of type C suffer damage of grade 3, a few of grade 4. Many buildings of type B show damage of grade 4; a few of grade 5. Many buildings of type A suffer damage of grade 5. Monuments and columns fall. Considerable damage to reservoirs;underground pipes partly broken. In individual cases railway lines are bent and roadways damaged.

c) On flat land overflow of water, sand and mud is often observed. Ground cracks to widths of up to 10 cm, on slopes and river banks more than 10 cm; furthermore a large number of slight cracks in ground ; falls of rock, many landslides and earth flows ; large waves on water. Dry wells renew their flow and existing wells dry up.

X General destruction of buildings

b) Many buildings of type C suffer damage of grade 4, a few of grade 5. Many buildings of type B show damage of grade 5 ; most of type A have destruction category 5 ; critical damage to dams and dykes and severe damage to bridges. Railway lines are bent slightly. Underground pipes are broken or bent. Road paving and asphalt show waves.

c) In ground, cracks up to widths of several dcm, sometimes up to 1 meter. Parallel to water courses occur broad fissures. Loose ground slides from steep slopes. From river banks and steep coasts considerable landslides are possible. In coastal areas displacement of sand and mud; change of water level in wells; water from canals, lakes, rivers etc. thrown on land. New lakes occur.

XI Catastrophe

b) Severe damage even to well-built buildings, bridges, water dams and railway lines; highways become useless; Underground pipes destroyed.

c) Ground considerably distorted by broad cracks and fissures, as well as by movement in horizontal and vertical directions; numerous land slips and falls of rock.

The intensity of the earthquake to be investigated specially.

XII Landscape changes

b) Practically all structures above and below ground are greatly damaged or destroyed.

c) The sirface of the ground is radically changed. Considerable ground cracks with extensive vertical and horizontal movements are observed. Falls of rock and slumping of river banks over wide areas; lakes are dammed; waterfalls appear, and rivers are deflected.

The intensity of the earthquake requires to be investigated specially.

Table 1

Magnitudes of the oscillations of earthquakes of different intensities

I (grade)	a (cm sec^{-2})	v (cm sec^{-1})	x_o (mm)
Y	12 - 25	1,0 - 2,0	0,5 - 1,0
YI	25 - 50	2,1 - 4,0	1,1 - 2,0
YII	50 - 100	4,1 - 8,0	2,1 - 4,0
YIII	100 - 200	8,1 - 16,0	4,1 - 8,0
IX	200 - 400	16,1 - 32,0	8,12- 16,0
X	400 - 800	32,1 - 64,0	16,1 - 32,0

I = Intensity of earthquake

a = Ground acceleration in cm sec^{-2} for periods between 0,1 sec and 0,5 sec.

v = Velocity of ground oscillation in cmsec^{-1} for periods between 0,5 sec and 2,0 sec.

x_o = Amplitude of movement of centre of gravity of the pendulum mass in mm. The natural period of the pendulum is 0,25 sec, the logarithmic decrement is 0,5 (8% of critical damping).

Table 2

Types of structures (A,B,C), number and classification of damage (1,2,3,4,5) to buildings

Intensity grade	Types of structures		
	A	B	C
Y	Single - 1		
YI	Single - 2 Many - 1	Single -1	
YII	Single - 4 Many - 3	Many -2	Many - 1
YIII	Single - 5 Many - 4	Single - 4 Many - 3	Single - 3 Many - 2
IX	Many - 5	Single - 5 Many - 4	Single - 4 Many - 3
X	Most - 5	Many - 5	Single - 5 Many - 4

Table 3

Short characterization of the earthquakes

Intensity (Grade)	
I	Only recorded by seismographs
II	Only felt by individual people at rest
III	Only felt by a few people
IY	Felt by many people. Dishes and doors rattle

Y	Hanging objects swing, many sleeping people awake
YI	Slight damage in buildings and small cracks in plaster
YII	Cracks in plaster, gaps in walls and chimneys
YIII	Wide gaps in masonry, parts of gables and corn-ices fall down
IX	In some buildings walls and roofs collapse, landslips
X	Collapses of many buildings, cracks in ground up to widths of 1 m
XI	Many cracks in ground, landslips and falls of rocks
XII	Strong changes in the surface of the ground

Table 4

Converting table for seismic scales

Seismic Scale MSK 1964	Scale of the Inst. of Physics of the Earth, USSR, 1952	American Modified Mercalli Scale (MM)1931	Japanese Scale 1950	Rossi-Forel Scale 1873	Mercalli-Cancani-Sieberg Scale 1917
I	1	I	0	I	I
II	2	II	1	II	II
III	3	III	2	III	III
IY	4	IY	2,3	IY	IY
Y	5	Y	3	Y-YI	Y
YI	6	YI	4	YII	YI
YII	7	YII	4,5	YIII	YII
YIII	8	YIII	5	IX	YIII
IX	9	IX	6	X	IX
X	10	X	6	X	X
XI	11	XI	7	X	XI
XII	12	XII	7	X	XII