Consultation Paper
for Introducing Seismic-resistant
Building Design Standards in Hong Kong

屋宇署
BUILDINGS DEPARTMENT

Consultation Paper

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in Hong Kong

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Executive Summary

Hong Kong is not geographically situated within active seismic belts. Hence, the possibility of serious earthquakes striking the territory is relatively low. However, minor earthquakes of perceptible intensities are detected from time to time. While the current Buildings Ordinance (Cap. 123) does not require private buildings in Hong Kong to meet specified seismic-resistant design standards, internationally many major cities and economies located in areas of seismicity comparable to that of Hong Kong have all introduced statutory seismic-resistant design standards for new buildings.

2. Since Hong Kong is prone to typhoons, most buildings in the territory are, as required by statute, built with a load-resisting capacity to withstand strong winds. According to a consultancy study commissioned by the Buildings Department, local buildings are basically safe in the event of an earthquake, although they may suffer some degree of structural damage depending on the intensity of the earthquake. The study also observed that the introduction of seismic-resistant building design standards in Hong Kong should not, generally speaking, lead to a substantial increase in construction costs, but should significantly reduce the annual damage cost to the structural elements of the buildings due to earthquakes. Moreover, the number of fatalities in the event of an earthquake would also be significantly reduced.

3. Taking into account the international practice, the potential improvement in building safety standards, the anticipated increased protection for properties and lives, as well as the marginal impact on construction costs, we consider that there may be a case for introducing statutory seismic-resistant building design standards for new buildings, and for major alteration and addition works in existing buildings in Hong Kong.

4. This consultation paper outlines details of the proposal. Views from stakeholders of the building industry, academics and the general public are sought on whether statutory seismic-resistant building design standards should be introduced in Hong Kong.

CHAPTER 1 - INTRODUCTION

Hong Kong is not geographically situated within active seismic belts. The possibility of serious earthquakes striking the territory is relatively low. However, minor earthquakes of perceptible intensities are detected from time to time by the Hong Kong Observatory and the general public.

2 Many major cities and economies located in areas of seismicity comparable to that of Hong Kong, including Shanghai, South Korea, Thailand, Australia, France, Germany and New York City, have all introduced the statutory seismic-resistant design requirements to new buildings.

3. Unlike those in many other international cities of similar seismicity, buildings in Hong Kong are not required by law to meet specific seismic-resistant standards in design and construction. According to the findings of a consultancy study commissioned by the Buildings Department (BD), the possibility of having serious earthquakes in Hong Kong is low. Basically most of the buildings and people are safe in the event of an earthquake despite encountering some degree of structure-related damages and suffering certain levels of injuries. Taking into account the benefits for introducing seismic-resistant building design standards, we consider that the proposal is a cost effective way to enhance the building safety in Hong Kong and is in line with international practice.

4. We aim to consult the stakeholders, including the building professional institutes, building developers' association, building contractors associations and local academics, as well as the general public on whether statutory seismic-resistant building design standards should be introduced in the design and construction of new buildings, as well as major alteration and addition works in existing private buildings.

5. The objectives of the consultation exercise are:

(a) to introduce the findings and recommendations of the consultancy study commissioned by the BD and the benefits for introducing seismic-resistant building design standards in Hong Kong; and

(b) to collect views on the introduction of seismic-resistant building design standards in Hong Kong.

CHAPTER 2 - JUSTIFICATIONS

Risk of Earthquake and International Practice

6. Buildings[1] in Hong Kong are currently not required by law to meet specific seismic-resistant design standards. Minor earthquakes of noticeable intensities are detected from time to time. Between 1905 (i.e. when seismic record began in Hong Kong) and August 2012, 169 earthquakes of varying intensities were registered in Hong Kong. Most of them were of Intensity V or below on the Modified Mercalli Scale [2] (MMS) and none had caused any casualties. The strongest earthquake ever recorded in Hong Kong measured Intensity VI to VII on the MMS. This earthquake occurred in 1918 with epicentre at about 300 kilometres away from Hong Kong in the neighbourhood of Shantou. In Hong Kong, it caused some damage, mainly cracks in walls, to a few buildings which were constructed to the less advanced building standards at that time. No injuries or casualties in the territory were reported. For reference, the MMS, with description of the impact at different levels of intensity, is attached at **Annex A**.

7. On the other hand, it is worth noting that, internationally, many major cities and economies located in areas of seismicity comparable to that of Hong Kong, including Shanghai, South Korea, Thailand, Australia, France, Germany and New York City, have all introduced statutory seismic-resistant design standards for new buildings.

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[1] In the Buildings Ordinance (BO), "building" is defined as "includes the whole, or any part, of any domestic or public building or building which is constructed or adapted for use for public entertainment, arch, bridge, cavern adapted or constructed to be used for the storage of petroleum products, chimney, cook-house, cowshed, dock, factory, garage, hangar, hoarding, latrine, matshed, office, oil storage installation, out-house, pier, shelter, shop, stable, stairs, wall, warehouse, wharf, workshop or tower, sea-wall, breakwater, jetty, mole, quay, cavern or any underground space adapted or constructed for occupation or use for any purpose including its associated access tunnels and access shafts, pylon or other similar structure supporting an aerial ropeway and such other structures as the Building Authority may by notice in the Gazette declare to be a building".

[2] The Modified Mercalli Scale (MMS) indicates the intensity of an earthquake. The intensity of an earthquake at a particular locality is a measure of the violence of earth motion produced there by the earthquake. It is determined from reported effects of the tremor on human beings, furniture, buildings, geological structure, etc. The MMS classifies earthquake effects into twelve grades ranging from Intensity I: "Not felt except by a few under especially favorable conditions" to Intensity XII: "Damage total, lines of sight and level distorted, objects thrown into the air". For Intensity V, the description is: "felt by nearly everyone, many awakened, some dishes and windows broken, unstable objects overturned, pendulum clocks may stop".

Seismic-Resistant Design Requirements and Possible Damage Cost

8. Although buildings in Hong Kong are not specifically built for earthquake-resistant, most of the buildings, as required by statute, have been designed and built with a relatively high load-resisting capacity to withstand strong winds as Hong Kong is prone to typhoons. As a result, they could generally meet the current performance-based seismic building design criteria accepted in international practice although they may still experience different levels of damage in an earthquake. Seismic-resistant building designs involve dedicated design and detailing requirements (e.g. detailing of steel reinforcing bars inside concrete structures, requirement for building separation to avoid pounding, etc.), which fall beyond the scope of Hong Kong's current statutory wind-resistant building design standards.

9. According to a consultancy study commissioned by the BD, a low intensity earthquake measuring MMS Intensity V to VI, which has an estimated return period of 1 in 72 years, 0.27% of the existing building floor area in Hong Kong may suffer "moderate damage" with large cracks in beams, columns, walls, etc. In a moderate earthquake of MMS Intensity VII, which has a return period of 1 in 475 years, 3.9% of the existing building floor area in Hong Kong will suffer similar damage. An earthquake of this magnitude may also cause "extensive damage", with spalling of concrete, deformation of reinforced concrete beams and columns as well as extensive cracking of unreinforced elements, to 0.19% of the existing building floor area. Besides, 0.003% of the existing building floor area may suffer "complete damage". A high intensity earthquake measuring MMS Intensity VIII, which has a return period of only 1 in 2 475 years, would, as can be expected, cause more severe damages. In such a serious earthquake, it is estimated that 16.5% of the existing building floor area in Hong Kong may suffer "moderate damage", 2.8% may suffer "extensive damage" and 0.19% may suffer "complete damage". Of the 0.19% which may suffer "complete damage", between 5% and 15% of the buildings involved may collapse. Details of the consultant's assessment are tabulated in **Annex B**.

10. Taking into account the probability of occurrence of different intensities of earthquakes and the associated extent of damage, the annual damage cost to the structural elements of the existing building stock resulting from earthquakes is estimated to be around $600 million[3]. On the other hand, had the total building stock in the territory been constructed in accordance with the seismic-resistant design requirements of the United States' International Building Code 2006 (IBC 2006)[4], the estimated annual damage cost to the structural elements of the buildings due to earthquakes could be reduced by some 80%, to the order of only $120 million[3].

Seismic-Resistant Design Requirements and Possible Injuries/Casualties

11. Depending on the intensity, earthquakes may cause different levels of injuries or casualties. The estimated impact on lives, under different scenarios and with our existing building stock which are not built to seismic-resistant design standards, is presented in **Annex C**. According to the consultant, the number of fatalities in case of an earthquake in Hong Kong would be significantly reduced if IBC 2006, or the current IBC 2009, is imposed on the total building stock in the city. For instance, in a high intensity earthquake (MMS Intensity VIII), the estimated average number of fatalities would fall from 130 - 150 to only three on average, if IBC 2006 is adopted.

Seismic-Resistant Design Requirements and Construction Cost

12. It is recognised that the incorporation of seismic-resistant standards in the design and construction of buildings could lead to higher costs. However, according to the consultancy study, the increase, especially for regular buildings, would not be high. As an illustration, based on the structural forms[5] commonly adopted for residential buildings in Hong Kong and assuming the adoption of IBC 2006, the consultant estimated that the increase in the construction cost (i.e. labour and material costs) of new residential buildings would range from 0% to

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[3] The annual damage cost is derived from the total damage costs predicted at 2011 price level under the three levels of earthquake intensities stated in Annex B. It is an average value estimated over an extended exposure period of hundreds of years

[4] The IBC 2006 has been superseded by IBC 2009 which provides detailed refinement to the former without causing significant implications on costs.

[5] Reinforced concrete frame buildings and reinforced concrete shear wall buildings.

0.3% or $40 per square metre of building floor area, compared to the medium construction cost of $13,400 per square metre[6]. If the Mainland "Code for Seismic Design of Buildings[7]" were adopted, the corresponding increase in construction cost of new residential buildings would be about 0.9%, or $120 per square metre of building floor area. Such increase in construction cost should be regarded insignificant. As regards buildings with transfer plate construction, they are classified as irregular structures under the Mainland "Code for Seismic Design of Buildings" and may require specific study for each individual case. For the purpose of illustration, it is estimated that the increase in the construction cost of new residential buildings with transfer plate construction may range from 0% to 5%, up to $670 per square metre of building floor area.

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[6] The increase in construction cost was estimated at the price level of 2011. $13,400 per square metre is the medium construction cost of good quality high-rise residential buildings in Hong Kong recorded in 2011

[7] The Mainland also issued a "Code for Seismic Design of Buildings" (GB50011-2001) in 2001 jointly by the then Ministry of Construction and the General Administration of Quality Supervision, Inspection and Quarantine. The Mainland's "Code for Seismic Design of Buildings" was superseded by GB50011-2010 in December 2010. As far as seismic-resistant design is concerned, the GB50011-2010 provides detailed refinement to the GB50011-2001 without having significant implications on cost terms.

CHAPTER 3 – THE PROPOSAL

13. Taking into account the international practice and our status as an advance city of the world, the potential improvement in building safety standards, the estimated reduction in damage cost, injuries and casualties, as well as the marginal impact on construction costs, we consider that there may be a case for introducing statutory seismic-resistant building design standards for new buildings, and major alteration and addition works in existing buildings in Hong Kong.

14. Since the specific ground motions, building designs, construction standards and practices of different localities are different, it will not be appropriate for Hong Kong to simply follow the seismic-resistant design requirements of other countries or territories. A tailor-made code, taking into account the relevant international standards and Hong Kong's geology, topography and construction practices, should be formulated if statutory seismic-resistant building design standards are to be introduced. We will make reference to the standards adopted by the United States, the Mainland and other cities/economies in devising Hong Kong's seismic-resistant design requirements. In line with international practice, consideration will be given to imposing more stringent requirements for new buildings, and major alteration and addition works carried out in existing buildings, of special nature having a post earthquake recovery role, the majority of which are Government buildings, as well as schools, etc. Such design requirements and the types of buildings to be covered will be worked out then.

15. Most existing buildings in Hong Kong, in particular the newer and high-rise buildings, possess a very high load-resistant capacity to withstand strong winds and, therefore, could generally meet the current performance-based seismic design criteria accepted by international practice. However, their construction was based on the statutory building standards prevailing at the time of their design and construction and it would not be a practicable option to require them to comply with the new statutory seismic-resistant building design standards if introduced. For instance, their occupants might have to move out for any such works to be carried out or the operations in them might be seriously disturbed and users inconvenienced. In some cases, the works would simply not be implementable technically. Besides, whilst some very old buildings (e.g. unreinforced masonry buildings) may suffer from different degrees of damage in case of a major earthquake, the damage risk to the vast majority of our building stock should remain small. Therefore, also as in

line with international practice[8], any new seismic-resistant building design standards, if introduced, should not be applied retrospectively to existing buildings.

16. Nevertheless, when major alteration and addition works are to be carried out in an existing building, we should require the incorporation of the new statutory seismic-resistant building design standards. As major alteration and addition works[9] often involve extensive modifications of structural elements of buildings, it would be opportune to include the additional seismic-resistant requirements in the design of such works. Where historic buildings are involved, we would have to take into account the need to maintain the authenticity and integrity of the buildings concerned in working out an appropriate mechanism.

17. The proposed imposition of seismic-resistant building design requirements on future new buildings, and major alteration and addition works in existing buildings aims to enhance safety of building structures and reduce building structure-related damages and injuries during earthquakes. If a building can remain intact during earthquakes, it will greatly enhance the safety of the occupants and properties therein. The basic operations within the buildings could also be ensured. Any new requirements will only cover the general structural elements of buildings, but not the building services and utilities (e.g. fire service installations, water supply system, gas mains, telecommunication networks, etc.). Each of these installations in a building has its own unique features and will require dedicated specialist considerations of seismic design. While we encourage the voluntary incorporation of seismic design requirements in such items in individual Government or private developments, we do not propose to impose mandatory requirements at this stage.

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[8] In New York City, Shanghai, South Korea, Thailand, Australia, France and Germany, seismic rules have not been imposed on existing buildings.

[9] The definition of "major alteration and addition works" will be formulated at a later stage, by making reference to the scale and nature of the works involved as well as international practice. As an illustration, in the regulations of New York City, United States, the extent of application of seismic requirements to the existing building, if so required, depends on the ratio of cost of the alteration and addition works to the value of the building.

CHAPTER 4 – IMPLICATIONS OF THE PROPOSAL

18. The implications of introducing seismic-resistant building design standards for future new buildings, and major alteration and addition works in existing buildings are set out below.

19. BD's consultant estimated that if IBC 2006 is adopted to meet the proposed seismic-resistant design requirements, the increase in the construction cost (i.e. labour and material costs) of new residential buildings will be up to $40 per square metre of building floor area[10]. If the Mainland's "Code for Seismic Design of Buildings" is adopted, the increase will be about $120 per square metre of building floor area[10]. In return, the present value of the resultant fall in damage cost to structural elements of buildings (if IBC 2006 were adopted) over 50 years design life of the building is estimated to be around $35 per square metre of building floor area[10]. The new seismic-resistant design requirements will also help reduce the number of casualties in the event of an earthquake.

20. The incorporation of seismic-resistant design will also raise the construction cost for major alteration and addition works, the amount of which will vary widely depending on the scope and nature of the works, the layout and structural form of the existing building, the selection of construction materials, etc.

21. Imposition of seismic-resistant design requirements on new buildings as well as major alteration and addition works in existing buildings will improve building safety standard, and reduce damage, injuries and the cost so resulted in the event of an earthquake. This initiative is in line with the sustainability principle of providing a living and working environment and pursuing policies which promote and protect the physical and mental health and safety of the people of Hong Kong.

22. The proposed imposition of seismic-resistant design requirements will bring about a positive environmental impact as it will reduce building damage, injuries and reconstruction cost in the event of an earthquake.

[10] The increase in construction cost and reduction in annual damage cost were estimated at the price level of 2011

CHAPTER 5 – THE CONSULTATION EXERCISE

23. The proposed introduction of seismic-resistant building design standards for private buildings and major alteration and addition works of existing buildings aims to bring the design and construction of buildings in Hong Kong in line with international practice and to enhance the building safety by reducing building structure-related damages and injuries in the event of an earthquake.

24. This consultation exercise is scheduled to commence in mid October 2012 and will last up to 28 February 2013. The following stakeholders of the building industry and the general public will be included in the consultation exercise:

(a) <u>Professional institutes</u>
- (i) Hong Kong Institution of Engineers;
- (ii) Hong Kong Institute of Architects;
- (iii) Hong Kong Institute of Surveyors;
- (iv) Hong Kong Institution of Steel Construction; and
- (v) Hong Kong Concrete Institute.

(b) <u>Associations</u>
- (i) The Real Estate Developers Association of Hong Kong;
- (ii) Hong Kong Construction Association; and
- (iii) Hong Kong General Building Contractors Association.

(c) <u>Academics</u>
- (i) The University of Hong Kong;
- (ii) The Hong Kong University of Science and Technology;
- (iii) The Chinese University of Hong Kong;
- (iv) Hong Kong Polytechnic University; and
- (v) City University of Hong Kong.

(d) <u>Others</u>
- (i) Building Sub-committee (BSC) of the Land and Development Advisory Committee; and
- (ii) Authorized Persons, Registered Structural Engineers and Registered Geotechnical Engineers Committee (APSEC).

(e) General public.

25. The BD will conduct two discussion forums in November 2012 and January 2013 for the professional institutes, associations and academics listed in paragraph 24(a) to (c) above. Details of the forums together with a questionnaire will be sent to the corresponding bodies direct in mid-October 2012. Completed questionnaires will be collected by the corresponding organizations and returned to the BD in batch toward the end of the consultation exercise.

26. Members of the BSC/APSEC will be consulted through the established channel.

27. Two public consultation forums are to be conducted for the general public in December 2012 and February 2013 to introduce the findings of the consultancy study and objectives of the consultation, and to collect their views. Details of the public consultation forums are as follows:

Date :	(i) 1st forum: 10 December 2012 (ii) 2nd forum: 1 February 2013
Time:	3:00 pm – 5:00 pm
Venue:	4/F, Conference Hall Hong Kong Productivity Council Building 78 Tat Chee Avenue Kowloon Tong, Kowloon

For those who are interested in attending the public consultation forums, please register your reservation by filling this reply slip https://brms.bd.gov.hk/wrbr/replyslip.jsp and return to BD on-line. For those who would like to express their views, whether or not they have attended the public consultation forums, please fill in a questionnaire by clicking https://brms.bd.gov.hk/wrbr/questionnaire.jsp and return to BD on-line. Alternatively, the reply slip and/or the questionnaire can be returned to BD by facsimile or post as follows:

By Facsimile : 2626 1762

By Post : Technical Services Unit
Buildings Department
Unit 1620 – 1624 Level 16 Tower 1
Metroplaza 223 Hing Fong Road
Kwai Fong NT

Hardcopies of the consultation paper, questionnaire, and public consultation forum's reservation reply slip are also available for collection from the Buildings Department at 12/F Pioneer Centre, 750 Nathan Road, Kowloon.

Enquiries may be forwarded by email to seismic_enquiry@bd.gov.hk or by phone at 2398 3107.

28. Unless parties making submissions specify a reservation, we shall assume that they have permitted the Administration to reproduce and publish their views in whole or in part in any form and to use, adopt or develop any proposals put forward without the need for permission from or subsequent acknowledgment of the party making the proposals.

CHAPTER 6 – THE WAY FORWARD

29. At the end of the consultation exercise, a consultation report summarizing the outcome of the consultation will be compiled. Pending the outcome, the BD will consider the way forward on the introduction of the statutory seismic-resistant building design standards in Hong Kong.

Annex A

Mercalli Magnitude	Effects observed
I	Not felt except by a very few under especially favorable conditions.
II	Felt only by a few persons at rest, especially on upper floors of buildings. Delicately suspended objects may swing.
III	Felt quite noticeably by persons indoors, especially on the upper floors of buildings. Many do not recognize it as an earthquake. Standing motor cars may rock slightly. Vibration similar to the passing of a truck. Duration estimated.
IV	Felt indoors by many, outdoors by few during the day. At night, some awakened. Dishes, windows, doors disturbed; walls make cracking sound. Sensation like heavy truck striking building. Standing motor cars rocked noticeably.
V	Felt by nearly everyone; many awakened. Some dishes and windows broken. Unstable objects overturned. Pendulum clocks may stop.
VI	Felt by all; many frightened and run outdoors, walk unsteadily. Windows, dishes, glassware broken, books off shelves, some heavy furniture moved or overturned; a few instances of fallen plaster. Damage slight.
VII	Difficult to stand. Furniture broken. Damage negligible in building of good design and construction; slight to moderate in well-built ordinary structures; considerable damage in poorly built or badly designed structures; some chimneys broken. Noticed by persons driving motor cars.
VIII	Damage slight in specially designed structures; considerable in ordinary substantial buildings with partial collapse. Damage great in poorly built structures. Fall of chimneys, factory stacks, columns, monuments, walls. Heavy furniture moved.
IX	General panic. Damage considerable in specially designed structures, well designed frame structures thrown out of plumb. Damage great even in substantial buildings, with partial collapse. Buildings shifted off foundations.

Mercalli Magnitude	Effects observed
X	Some well built wooden structures destroyed; most masonry and frame structures destroyed with foundations. Rails bent.
XI	Few, if any masonry structures remain standing. Bridges destroyed. Rails bent greatly.
XII	Damage total. Lines of sight and level distorted. Objects thrown into the air.

Source: US Geological Survey

Annex B

Estimated Building Damages under Different Intensities of Earthquakes

	Low Intensity (Approximately MMS Intensity V to VI) (Probability of occurrence: 50% in 50 years, or frequency of occurrence: 1 in 72 years)		Moderate Intensity (Approximately MMS Intensity VII) (Probability of occurrence: 10% in 50 years, or frequency of occurrence: 1 in 475 years)		High Intensity (Approximately MMS Intensity VIII) (Probability of occurrence: 2% in 50 years, or frequency of occurrence: 1 in 2 475 years)	
Estimated building damage of significance and associated % of the entire building stock suffering from damage (expressed in % of building floor areas)	Moderate damage	0.27%	Moderate damage	3.9%	Moderate damage	16.5%
	Extensive damage	0.003%	Extensive damage	0.19%	Extensive damage	2.8%
	Complete damage	0%	Complete damage	0.003%	Complete damage	0.19% [1]

[1] In terms of number of buildings or dwellings damaged, 0.19% of building floor areas involves 1 000 village houses, 6 schools, 7 retail buildings, 5 public office buildings, 9 private office buildings, 5 industrial buildings, 2 emergency buildings, 1 carpark building, 640 public dwellings (not buildings) and 1 630 private dwellings (not buildings). Between 5% and 15% of the above buildings suffered from complete damage will collapse.

Damage level	Description of damage
Sight Damage	Hairline cracks in beams, columns and walls.
Moderate Damage	Large flexural cracks with some spalling. Large diagonal cracks in shear walls. Masonry walls may have large diagonal cracks.
Extensive Damage	Spalled concrete and buckled reinforcement in columns and beams. Visibly buckled reinforcement in shear walls. Most unreinforced elements will have suffered extensive cracking.
Complete Damage	The structure is in imminent danger of collapse due to brittle failure of beams and columns and most of the shear walls. Unreinforced masonry walls may collapse due to in-plane or out-of-plane failure.

Annex C

Estimated Injuries/Casualties under Different Intensities of Earthquakes

Injury Level	Intensity of Earthquake					
	Low Intensity (Approximately MMS Intensity V to VI) (Probability of occurrence: 50% in 50 years, or frequency of occurrence: 1 in 72 years)		Moderate Intensity (Approximately MMS Intensity VII) (Probability of occurrence: 10% in 50 years, or frequency of occurrence: 1 in 475 years)		High Intensity (Approximately MMS Intensity VIII) (Probability of occurrence: 2% in 50 years, or frequency of occurrence: 1 in 2475 years)	
	Night	Day	Night	Day	Night	Day
Severity 1	85	120	880	1 380	4 900	7 800
Severity 2	4	5	75	110	730	1 050
Severity 3	0	0	1	1	65	75
Severity 4	0	0	2	2	130	150

Injury Level	Injury Description
Severity 1	Minor injuries requiring basic medical aid without hospitalisation
Severity 2	Serious injuries requiring a greater degree of medical care and hospitalisation, but not expected to progress to a life threatening status
Severity 3	Injuries that pose an immediate life threatening condition if not treated adequately and expeditiously
Severity 4	Instantly killed or mortally injured