IDNDR ACTIVITIES OF THE WORLD ROAD ASSOCIATION (WRA/PIARC)

by

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ABSTRACT

In response to the United Nations proposal on IDNDR, the World Road Association (WRA or PIARC) organized a working group G2 " Natural Disaster Reduction," in 1990. The group conducts various studies on disaster reduction measures for roads in 1990-99. This paper briefly describes the results of its past activities and the future prospect.

Key Words : Emergency Management
Natural Disaster
Repair Methods
Road Disaster
Road Networks

1. INTRODUCTION

Many countries are always facing threat of destruction from natural disaster such as earthquakes and cyclones. In view of this fact, the United Nations declared the period of 1990-99 to be the International Decade for Natural Disaster Reduction (IDNDR), and prosed that special efforts should be made.

In response to the appeal of the United Nations, the World Road Association (WRA or its old nickname PIARC) proposed in 1989 to organize a special working group associated with IDNDR and to make its own action for reducing road-related disasters. Thus, Working Group G2 "Natural Disaster Reduction" started its studies in 1990, with Chairman T. Iwasaki of Japan and some 20 Members from various countries.

In view of the essential roles of road traffic at times of disaster, the Working Group G2 has conducted various investigations including an international survey on road disasters and published a report entitled "Comprehensive Report on Natural Disaster Reduction for Roads," in 1995.

In the Report the results of the international survey, including various natural events causing road disasters in 21 countries, are first introduced, and then pre-event measures for major kinds (landslide, earthquake, flood, and snow avalanche) are described in detail. Pre-event measures here include damage risk assessment, retrofit, and disaster preparedness plans.

Furthermore, repair methods, both temporary and permanent, for severely damaged road structures are illustrated. Disaster preparedness and emergency management such as organization for repair, and emergency survey and emergency operation for avoiding secondary disasters, are also discussed. The Comprehensive Report, consisting of 9 Chapters, are written in English and has a French summary.

2. INTERNATIONAL SURVEY ON ROAD DISASTER

2.1 OUTLINE

The G2 group conducted a questionnaire survey on road disasters in 1991 and 1992,and collected information relating to the likely types of damage to road and road transportion facilities which may cause major socio-economic problems as a result of natural events. The G2 received answers from 21 countries worldwide.

Table 1 shows the numbers of various natural disasters causing major road damage reported from 21 countries, of the 1991-92 survey. From the survey road disasters can be classified into five groups as follows:
1) Landslide, including debris flow, rock fall, and slope failure,
2) Earthquake,

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3) Flood,
4) Snow avalanche, and
5)Other hazards: volcanic eruption, tsunami, storm surge, dense fog, heavy snow, strong wind, wildfire, sand accumulation and downburst are examples.

Descriptions of four major disastrous events: Landslide, Earthquake, Flood, Snow Avalanche and related information will be given in Chapters 3 to 6 of this paper. Other Hazards and additional topics will be briefly explained in this Chapter (2.2-2.5).

2.2 EXAMPLES OF OTHER HAZARDS

Volcanoes : Volcanoes erupt molten lava, ash solid (or pyroclastic) fragments, steam and gases when the pressure of dissolved gas becomes high enough to burst the enclosing molten magma. Some eruptions produce mostly lava, which is liquid magma that moves down-hill away from the vent in stream known as lava flows. When lava flows advance and spread over roads, the roads are destroyed and buried by the lava flows. Ash falls also become obstacles to transportation because of deposits of ash on roads and vehicles and darkness caused by ash clouds.

When ashes and other volcanic debris have blocked rivers, major disasters have been caused by the resulting floods and by sudden releases of debris and water that flow rapidly and violently downstream, known as lahars. Mixtures of hot pyroclastic materials and gases erupted from craters sometimes flow very rapidly along steep slopes, known as pyroclastic flows, which may cause damage to road structures as well as casualties.

Table 1 Number of Various Natural Disasters Causing Major Road Damage [1]
(Reported from 21 Countries; 1991-92 Survey)

Country	Landslide	Earthquake	Flood	Avalanche	Other Hazards
Algeria	5	2	4	—	Sand Accumulation
Australia	—	1	9	—	—
Belgium	1	3	5	—	2 Fires, 2 Storms
Canada	5	1	5	—	—
Chile	5	5	5	5	3 Volcanoes, 2 Rainy Seasons
Denmark	—	—	—	—	—
Ecuador	2	2	1	—	—
France	5	—	—	—	—
Finland	1	—	2	—	—
Hungary	—	5	5	—	—
India	5	5	5	—	Cloudburst
Indonesia	3	—	—	—	—
Iran	—	5	5	5	—
Italy	5	7	6	1	2 Dense Fogs, 2 Heavy Snows
Japan	5	5	5	5	Volcano, Tsunami, Storm Surge, Dense Fog, Heavy Snow
New Zealand	4	2	8	1	Volcano
Norway	4	—	4	3	—
Philippines	—	1	1	—	Volcano
Saudi Arabia	1	—	1	—	—
Sweden	3	—	—	—	—
U.S.A.	5	5	5	4	Volcano, 4 Strong Winds
Total	59	48	76	24	7 Volcanoes, 4 Strong Winds, 3 Dense Fogs,3 Heavy Snows,2 Fires,2 Rainy Seasons,2Storms,Cloudburst,Sand Accumulation, Storm Surge, and Tsunami

Tsunamis : A tsunami is caused by seabottom deformation due to a submarine earthquake or landslide along the coastline. A tsunami propagates to the coast like a fast-rising tide, running inland and inundating roads, housing areas or farms. The extent of innundation depends upon the magnitude of the tsunami as well as the topography of the coastal area.

Storm Surges : A severe storm which hits a coast is usually accompanied by a storm surge, i.e., an abnormal rising of water produced by the strong wind pressure and a large decrease in atmospheric pressure. Typhoons and cyclones are generated frequently in the west of North Pacific Ocean and in the Indian Ocean. Coastal areas have suffered an enormous amount of damage, mainly severe inundation of roads, housing and farms, due to storm surges.

Dense Fogs : Fogs appear depending on meteorological and topographical conditions. A heavy fog restricts the visibility of drivers. On expressways, speed restrictions are enforced and sometimes the road is closed to avoid risks of traffic accidents.

Heavy Snows and Blizzards : The visibility of drivers is restricted by blizzards and sometimes stuck in heavy snow. On expressways, speed restrictions are enforced and the road is sometimes closed.

Wildfires : Wildfires such as forest fires sometimes block roads.

Sand Accumulation : In desert areas, sand accumulations may block roads, and drivers may lose their ways.

Downbursts : A mass of air moves down very rapidly and bursts in every direction on the ground surface.

2.3 IDNDR ACTIVITIES IN SELECTED COUNTRIES

IDNDR activities were reported from four countries: Ecuador, France, Japan, and U.S.A. The following summary is as of 1992:

Ecuador : 1) Disaster prevention plan against the phenomenon El Nino.
2) Disaster reduction plan for volcanic eruptions at: Tungu, Guagua, Pichincha, and Cotopaxi.
3) Disaster reduction plan against earthquakes in Esmeraldas and Guayas.

France : France created a national committee for IDNDR that includes three sections:
1) Earthquakes and volcanoes section,
2) Meteorological hazards section ,
3) Surface hazards section ,

The national projects in these sections are in the process of definition.

Japan : The government headquarters for IDNDR is set up in the National Land Agency headed by the Prime Minister. The Ministry of Construction has established an MOC headquarters for IDNDR, and is now promoting:
1) International cooperation on disaster prevention
2) Disaster countermeasures in Japan,and
3) Information supply and education .

U.S.A. : Aiming at reducing disaster toll, U.S.A. set up the U.S. Advisory Committee on USDNDR. Areas of U.S. activities are:
1) Prediction, 2) Land-use planning, 3) Education, 4) Postdisasater programs, 5) Social science, 6) Intra/Intergovernment issues, 7) Demonstration projects, 8) Basic research, 9) Data handling and Information flow, and 10) International activities

2.4 TECHNICAL ASSISTANCE REQUIRED

Chile, Ecuador, India, Japan, Philippines, and U.S.A. reported technical assistance required.

Chile : Chilean rivers have torrential characteristics and transport a lot of bedload. For the resulting work 14 buldozers are used. The maintenance has been done since 1986, however, the number of bulldozers is too small.

Ecuador : 1) Training of technical staff to manage emergency, referring especially to construction of Bailey type bridges,
2) Geological and technical studies to make maps of risky zones for stability of grounds and road banks, and
3) Study on work for flood control.

India : Exchange of literature on various landslide control techniques, instrumentation, analytical methods, case histories from other countries.

Japan : Exchange of information and cooperative studies for technical development.

Philippines : 1) Intensive investigation observation of seismic fault activities, earthquakes, and strong ground motions,
2) Reexamination of seismic design standards for bridges, buildings, and dams,
3) Reinforcement of disaster prevention measures,
4) Examination of redevelopment plans for areas where the sinking rate is high,
5) Review of alignment of major roads such as the Kennon road in Baguio city,
6) Establishment of a system for recovery from damage,
7) Countermeasure techniques gainst liquefaction, seismic diagnosis of existing buildings and other structures, and
8) Study of strong vibrations, predictive surveys and the establishment and operation of a strong motion observation network.

U.S.A. : No technical assistance is required as technical resources are already available from a number of public and private sources. A great need is to coordinate these sources in addressing the impact of natural hazards on road development.

2.5 REQUESTS TO PIARC WORKING GROUP G2

Six countries made requests to G2.
Ecuador : Requests are principally about pre-event preventive activities on protection of bridges, coating of riverbeds, work for flood control and slope stability.

France : Collecting information and knowledge on slope stabilization from other countries.

Iran : Presently there is no special request. Any proposals for training courses and workshops, forwarding of information on warning systems and equipment, and any other types of information required for compilation of technical knowledge in the areas of flood, earthquake, avalanche and landslide hazard control would be appreciated.

Japan : 1) To make an arrangement to reserve one or a half page of the bulletin Routes/Roads of PIARC for specific use of the G2 during the IDNDR period, so that the readers can learn large-scale natural disasters related to roads occurred in the world.
2) To hold workshops/seminars on IDNDR by PIARC G2. Those will provide access for members, particularly developing countries, to join in the IDNDR activities of PIARC G2.

Philippines : Earthquake countermeasures are not merely technical issue, but require consideration of economic and social conditions of the particular country. Technical assistance and cooperation plus aid are desired whenever possible. Presently we need help to determine degree of danger to stricken structures brought about by the recent surge of natural disaster (eruption of Mt. Pinatubo), and carry out emergency rehabilitation to minimize the influences of damage to economic activities, since the present situation will be likely to continue for some time.

U.S.A. : 1) To develop, publish and disseminate guidance to mitigate the effects of natural disasters on roads. Typical procedure for prediction, prevention, preparedness and postdisasters assessment are potential study topics.

2) To collect and disseminate the following information from each PIARC member country :
a)National sources of information on natural hazards
b)Past (10 years), present and proposed research efforts pertaining to natural hazard dentification, investigation, and mitigation.
c)Training materials available for courses associated with natural hazard identification, investigation, and mitigation.

3. LANDSLIDES

3.1 GENERAL FEATURES

Landslides include various types of mass movement of rock and soil sliding down a slope, such as slides, flows, failures, and falls. These types are illustrated in Table 2 and Fig. 1. The characteristics and major causes of each type landslide can be described as follows:

Slides are slow movements occurring on slopes with a gradient of 5-30° . They occur mostly in places with particular geology or geological formations, such as where there is overconsolidated clay or shattered rocks along large tectonic lines. They are also greatly affected by ground water conditions. Most flows are wet and high speed moving masses with a rate of movement more than a few meters per second. Debris flows and mud flows are caused by rainfall or volcanic activities, and occur in valleys steeper than 3° gradient. Slope failures and rockfalls are rapid mass movements where there is a gradient more than 30° . They occur in loose layers such as talus, weathered rock, pyroclastic deposits and well-jointed rocks, and may be triggered by heavy rainfall or earthquake.

Water from rainfall, snow melting, or reservoirs which reduces soil strength is the most general cause of landslides. Cutting slopes or embankments for road construction also reduce slope stability.

Most landslides are caused by heavy rain or earthquake, but in the areas of quick-clay distribution in North Europe and North America, landslides are caused by small changes in slope stability from earthwork or erosion.

3.2 LANDSLIDE EFFECTS ON ROADS

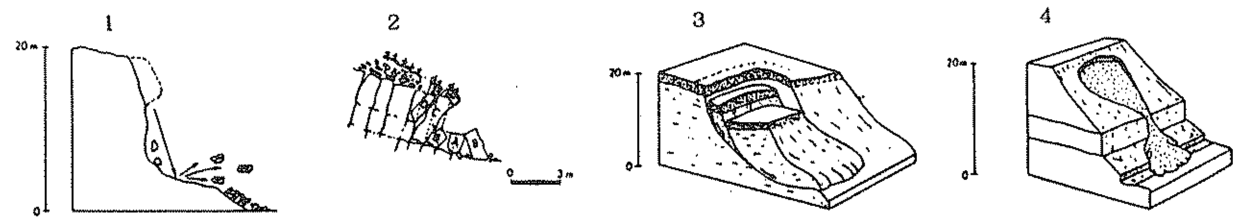
Landslides frequently cause interruption to traffic by collapse of roads or collapsed material from the upper slopes, bridge failures due to debris flows, and direct damage to vehicles from high-speed mass movement such as falls or slope failures.

The effects of landslide-induced road damage on socio-economic activities are village isolation, house relocation, evacuation of persons, increase in prices of commodities, and so on. Well-developed road networks, however, can minimize those effects. The sediment area of a rock fall or small slope collapse is not usually wide, and the damage is mall.

In less developed areas landslides tend to occur many times at the same location in the

Table 2 Classification of Landslide Types [1]

Type of Movement			Type of Material		
			Bedrock	Engineering Soils	
				Mostly Coarse	Mostly Fine
Falls			Rock Fall	Debris Fall	Earth Fall
Slides	Rotational	Few Units	Rock Slump	Debris Slump	Earth Slump
	Translational		Rock Block Slide	Debris Block Slide	Earth Block Slide
		Many Units	Rock Slide	Debris Slide	Earth Slide
Lateral Spreads			Rock Spread	Debris Spread	Earth Spread
Flows			Rock Flow	Debris Flow	Earth Flow
Complex			Combination of two or more Principal Types of Movement		



1) Fall; 2) Topple; 3) Slide; 4) Flow.
Broken lines indicate the original ground surface, arrows show portions of the trajectories of individual particles of the displaced mass.

Fig. 1 Types of Landslides [3]

monsoon or rainy season. Where construction of a temporary road is difficult, long detours have to be used. Continuous movement of a large-scale slide makes restoration and prevention work difficult, and the original route must be changed. A landslide which occurs in an urban area causes damage not only to roads but also to infrastructure along roads, such as water supply and sewer pipes.

4. EARTHQUAKES

4.1 GENERAL FEATURES

When a large earthquake strikes, road networks in the affected area play very important role in providing evacuation routes for victims and transportation routes for staff and materials for repair. This role can be secured by undertaking immediate repair soon after the quake outbreak and making the road networks functional.

The character of damage to roads depends on many factors such as earthquake magnitude, epicentral distance, and geographical and geological conditions. Accordingly, it is difficult to predict every aspect of damage to road structures. Furthermore, for social and economic reasons it is impossible to complete seismic retrofit for all road structures within a short period.

For reducing seismic damage to roads, it is essential to take pre-event measures prior to an event. Pre-event measures include damage risk assessment and seismic retrofit. In conducting retrofit, it is important to consider the social and economic character of the route and the probability of serious disasters due to road damage.

4.2 SEISMIC EFFECTS ON ROADS

Past earthquakes caused varieties of damage to roads. Fig. 2 outlines a classification of seismic damage to roads into three categories: (A) road damage due to ground shaking, (B) effects of damage to auxiliary facilities along roads, and (C) other effects such as those of tsunami and fire which may prevent the use of roads.

Roads are effective when their networks are maintained. Damage to those roads which do not have any detour routes has extensive impacts on social and economic activities of the communities in the vicinity of the damaged sections. When a strong earthquake hits a region and many roads suffer serious damage in a very large area, it is crucial to restore arterial roads going through the region and to make them functional as soon as possible. Until those roads are restored, it is difficult to perform rescue operations smoothly and to repair seriously suffered facilities in the areas.

Duration of repair of damaged roads largely depends on damage type. Table 3 shows a relation between the damage pattern to road sections and the approximate duration to repair and reopen. It is important to notice the following features regarding damage patterns and repair duration:

1) Frequent damage patterns are road surface damage (cracks and bank settling),and slope failures in mountain areas.

Seismic Damage to Roads
- (A) Road Damage due to Ground Shaking
  - Road Surface Damage
  - Bridge Damage
  - Embankment Damage
  - Mountain Slope Failure
  - Tunnel Damage
- (B) Effects of Auxiliary Facilities along Roads
  - Damage to Buried Utilities
  - Damage to Buildings and Fences
  - Toppling of Trees and Poles
- (C) Other Effects
  - Inundation (Tsunami and Flood)
  - City Fires and Car Fires
  - Traffic Jams and Abandoned Cars

Fig. 2 Classification of Seismic Damage to Roads [1,2]

2) Bridge damage and large slope failure take a fairly long time for repair and reopening.

5. FLOODS

5.1 GENERAL FEATURES

Floods are natural phenomena caused by overflowing of river water due to heavy rain or snow melting. Floods have caused numerous disasters to road facilities such as road embankments and bridge structures in many countries. Besides direct damage to facilities, indirect damage such as disruption of the transportation system has been caused by floods.

Principal types of flood damage to road facilities are catergorized as follows:

1) Interruption of road transportation due to submergence of the road surface.

2) Washout of bridges, road embankments, culverts, and retaining walls.

3) Settlement, inclination or toppling of bridge piers due to scouring. In the worst case, the bridge superstructure may fall.

4) Burying of bridge and road surface by aggrading of the river bed.

5) Break in the road due to diversion of the main river channel.

5.2 LESSONS LEARNED FROM PAST FLOODS

Many countries pointed out the characteristics of damage due to scouring. The following outlines lessons learned from the past flood experiences.

1) Temporary bridge systems, like Bailey bridges, logs and planks, and rolls of wire netting for temporary restoration work with stone sausages or gabions should be kept ready.

2) Existing bridges on pile foundations showed very good stability against floods.

3) Impact from heavy buoyant debris, such as wooden logs, caused more damage to structures than flood water caused.

Table 3 Seismic Damage Patterns to Roads and Time to Repair and Reopen [1,2]

Road Sections	Damage Patterns	Approximate Duration to Repair and Reopen								
		Hours		Days			Months		Years	
		1	3	1	3	7	1	3	1	3
Embankment on Flat Plain	Crack, Settling, Bump, Swell	- - -	- - -	- - -	- - -	- - -	- - -			
	Collapse (Slide, Flow)			- - -	- - -	- - -	- - -			
Mountainous Road with Steep Slope (Cut and Bank)	Small Slope Failure, Rockfall, Erathfall			- - -	- - -	- - -	- - -			
	Large Slope Failure, Collapse (Slide, Flow)						- - -	- - -	- - -	
	Girder Fall						- - -	- - -	- - -	
	Superstructure Failure (Movement, Buckling)				- - -	- - -	- - -			
Bridge	Failure of Bearing Support				- - -	- - -	- - -			
	Crack, Failure of Substructure (Column, Foundation)				- - -	- - -	- - -			
	Settling of Approach Bank		- - -	- - -						
Tunnel	Erathfall on Tunnel Entance due to Slope Failure			- - -	- - -					
Lowland Road	Innundation due to Tsunami					- - -	- - -			
Urban Street	City Fire			- - -	- - -					
	Traffic Jam, Abandoned Cars				- - -	- - -				
Auxiliary Systems (Signal,Fence,Pole)	Fall and Toppling onto Roads			- - -	- - -	- - -				

4) Until a temporary structure was completed,the additional travelling had a significant effect on the lives of the local population, causing additional travel time and costs.

6. SNOW AVALANCHES

6.1 GENERAL FEATURES

Snow avalanches are phenomena caused by release of snow cover due to meteorological and artificial factors. Avalanches have caused numerous disasters to roads such as traffic blockage, damage to automobiles, and destruction of retaining walls.

6.2 DAMAGE EXAMPLES AND COUTERMEASURES

Typical types of snow avalanche damage to roads can be categorized as follows:

1) Interruption of road transportation due to snow debris on the road.

2) Damage to moving vehicles and to road structures.

The past avalanche damage to roads has indicated the following lessons:

1) Prediction and forecast systems should be established to reduce avalanche damage.

2) Information network systems should be organized to reduce traffic interruption.

The following measures are effective to reduce road damage by snow avalanches:

1) Avalanche-prone slopes should be selected and identified.

2) A study should be made on reasonable criteria for avalanche prevention facilities.

3) Snow cover should be artificially removed from slopes where avalanches tend to occur.
4) Avalanche prevention facilities should be installed.
5) Avalanche forecast systems should be upgraded.

6) Education and training to cope with snow avalanches should be enhanced.

7. REPAIR METHODS

7.1 GENERAL

When roads sustain severe damage from events such as landslides and earthquakes, repair is normally performed in two stages: temporary repair and permanent repair.

Temporary repair implies quick repair on heavily damaged structures to open the particular section for emergency use. Since a primary objective of temporary repair is to restore traffic as soon as possible, various restrictions may be necessary, such as limitations on sections and lanes that can be used, types and weight of vehicles permitted,driving speed, and hours when the road is open to ordinary traffic.

Permanent repair, on the other hand, is reliable repair for which the necessary time and resources can be assigned. In this stage proper methods can be chosen, in view of the kind of damage, future importance, economic considerations, and expected remaining life of structures that need repair.

7.2 ROAD SURFACE REPAIR METHODS

When there are large cracks and major settling of road surfaces, adequate methods for temporary repair should be selected from the following, in order to quickly reopen:
1) Filling with earth and other materials,
2) Filling with asphalt,
3) Filling with mortar Or concrete
4) Injecting resin,

7.3 BRIDGE REPAIR METHODS

In accordance with the location and type of bridge damage, proper permanent repair methods may be selected from the following examples:

For Foundations:

1) Widening footings and adding piles
2)Construction of underground walls and beams, and steel sheet piles

3) Ground improvement and earth-anchoring
4)Reinforcement with large stones around affected foundations
5) Total replacement

For Reinforced Concrete Structures:

1) Injecting resin, plastics, mortar, or concrete into openings
2) Lining by RC or steel plates around heavy cracks
3) Adding RC shear walls
4) Banding by steel belts
5) Total replacement

For Steel Structures:

1) Concrete pouring into cross section of steel box columns
2) Adding steel plates outside steel piers
3) Lining steel piers by RC
4) Replacing damaged structural members
5) Total replacement

7.4 EMBANKMENT REPAIR METHODS

In accordance with the repair objectives of damaged embankments, appropriate permanent repair methods may be selected from the following:

To Secure Stability against Rainfall:

1) Drain
2) Asphalt curb

To Maintain Traffic Flow:

1) Banking and paving
2) Asphalt seal
3) Asphalt injection into void and opening

To Strengthen Embankments:

1) Banking
2) Construction of retaining walls
3) Construction of frameworks on bank slopes

To Strengthen Supporting Ground:

1) Additional banking on ground near bank feet
2) Soil improvement work such as soil densification
3) Draining underground water
4) Driving steel sheet piles

7.5 SLOPE REPAIR METHODS

In accordance with the principal repair objectives for failed mountain slopes, appropriate permanent repair methods may be selected from the following examples:

To Prevent Erosion, Collapse and Rockfalls at Slopes (Against Rainfall Effects)

1) Draining from surface and underground
2) Spraying mortar and concrete
3) Constructing masonry walls, concrete blocks and concrete walls on slopes
4) Construction of frameworks by precast concrete, cast-in-place concrete and spray concrete
5) Cutting unstable slopes

To Prevent Collapse and Rockfall at Slopes (Against Gravity Effects)

1) Cutting entire slopes
2) Construction of retaining walls by masonry, block or concrete
3) Anchoring slope surface into deeper rock by steel wires, rods, and bolts
4) Construction of frameworks
5) Counterweight fills
6) Preventing movement of unstable rocks by wire ropes and wire nets

To Restrain Movement of Unstable Soil and Rock along Slope Surface

1) Setting railings, of wooden piles and tree branches
2) Driving H-shape steel pile sheets and placing nets
3) Setting wire cages with stones along slopes

To Protect Road Traffic from Collapse and Rockfall

1) Placing wire nets with pocket space for catching falling rocks
2) Setting railings of H-shape steel poles, nets, ropes and expansible metals
3) Retaining walls with catch space
4) Adding covering road with steel or reinforced concrete shelters

8. DISASTER PREPAREDNESS AND EMERGENCY MANAGEMENT

8.1 GENERAL

Disaster reduction measures to prevent or reduce natural disaster to roads and their time phases can be shown as Fig. 3.

Overall measures can be grouped into three phases: regular work, pre-event measures and post-event measures. First, consideration of disaster reduction in the regular work consisting of planning, design, construction, and management is most crucial for mitigating natural hazards to roads.

Pre-event measures include damage potential assessment, retrofit work, and disaster preparedness.

Post-event measures consist of emergency measures (emergency survey and emergency operation) and repair work. Emergency survey is a quick survey to understand the nature and degree of damage to roads and facilities, with objectives of responding to the needs of emergency operation and repair. From the emergency survey the management staff should obtain an outline of all damage concerned.

Emergency operation may consist of disaster-relief aid for rescuing and searching for victims, and also actions for avoiding successive hazards which often follow the original event. Work to close and restrict the use of damaged roads and to install temporary supports for preventing complete collapse or partially damaged structures are typical emergency operations. The emergency survey and emergency operation will often be conducted consecutively as emergency measures.

8.2 PRE-EVENT PREPAREDNESS MEASURES

<u>Vulnerability of Road Network</u> : In addition to damage potential assessment, preevent preparedness measures are also very important.

Road management offices should thoroughly understand the vulnerability of road networks in the region concerned and availability of detours. Future additions of road networks should be considered for areas where most roads, including detours, are likely to seriously suffer from hazards.

<u>Road Management Systems</u> : Road offices should improve management systems with consideration of the following factors:

1) Collection of road damage information
2) Needs for emergency measures and repair
3)Cooperation with construction and materials

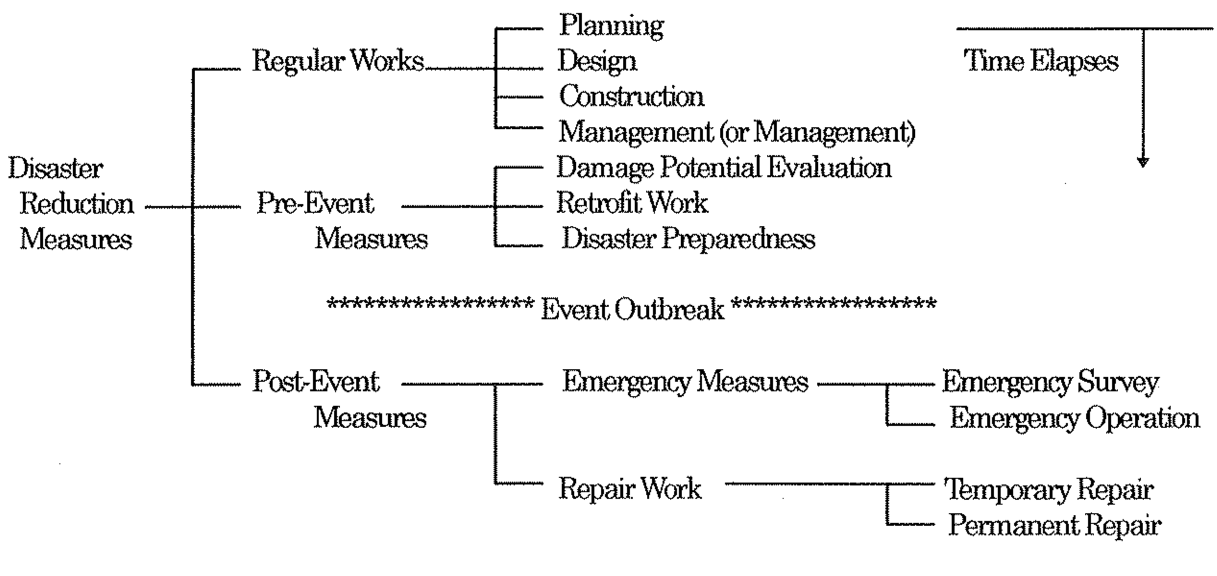


Fig. 3 Disaster Countermeasures and Time Phases [1,2]

delivery industries
4) Consultation with disaster experts
5)Storage of construction materials and equipment for emergency use
6) Call of off-duty staff.

Education, Training and Exercises : Road maintenance staff should be aware of possible results of road damage and the effects on society and on economic activities. Training exercises that assume a hypothetical disaster are effective in getting the staff accustomed to disaster situation. In these exercises an emphasis should be placed on actions to be taken just after road damage, and on procedures for communicating disaster information among the road offices.

8.3 POLICY AND ORGANIZATION FOR REPAIR

Procedures for Repair Work : When a hazardous event causes serious damage to roads and related facilities, some of the following measures should be taken, based on the type and magnitude of the disaster.

1) Call of staff members
2) Setup of emergency organization system
3) Emergency survey and emergency operation
4) Road closures and traffic restrictions
5) Temporary repair
6) Permanent repair

Emergency Organization : For smooth repair of damaged roads, it is effective to set up a special organization which copes exclusively with the repair work. When establishing a special system to cope with a serious road disaster, the following factors should be carefully considered.

1) Assignment of each staff member's role
2) Sufficient staff numbers for field teams
3) System for instruction and information collection
4)Portable communication system between responsible staff members
5) Consultation with experts and supervisors
6) Cooperation with specialized companies
7) Good care of staff health

Repair Plan and Repair Priority : In planning repair of damaged roads, the degree of the entire disaster, characteristics of the affected area, traffic demands, and repair priority should be considered.

Traffic Management : Traffic management should be adequately enforced, taking into account the pattern and degree of road damage. Appropriate control should be selected from different traffic control measures such as (a) complete closure, and (b) partial restriction in kind or weight of vehicles, time of opening, driving speed, lanes to open, or alternating one-way use.

Information Communication and Public Relations : For smooth implementation of repair work it is essential to have a good system for accurate information communication. In communicating with related organization immediately after a serious disaster, public telephones may not be available. In such cases disaster priority telephones, radio phones, or wireless phones may work effectively. Availability and effectiveness of these emergency communication media should be checked during normal times.
It is also important to work on public relations and provide local residents with updated information on road damage and repair prospects. Mass media such as newspaper, radio and television may be effectively employed for this purpose.

8.4 EMERGENCY MEASURES

Emergency Survey : Emergency survey is to obtain an outline of all the damage to road networks. In addition it is crucial to identify damaged portions which have high potential for subsequent complete collapse.

From the emergency survey the necessity to close roads or restrict their use should be judged in view of the relation between degree of road damage and road traffic use. An outline of damage to important structures such as long bridges should also be obtained. It is also essential to transmit the results of the emergency survey to the director at the headquarters office as soon as possible.

Emergency Operation : When serious road damage happens and causes accidents and injuries, the road management office should undertake first aid operations to rescue and search for victims, in cooperation with emergency aid organizations such as police and fire stations.

When damaged portions likely to result in complete collapse are found from the emergency survey, emergency operations such as closure and restrictions of road use, identification of dangerous areas, and warnings to road users should be executed promptly. In this way successive hazards can be avoided.

9. ACTIVITIES FOR THE SECOND TERM (1996-99)

9.1 OUTLINE

In succession to the the above investigations described in Chapters 2 through 8,the G2 Group (with 23 members from 19 countries; Chairman: T. Iwasaki) is now focusing the following 4 topics from 1996 to 1999:

1) Updating the Comprehensive Report
2) Holding G2 Seminars
3) Review of Codes and Guidelines
4) Emergency Planning and Management

9.2 UPDATING THE COMPREHENSIVE REPORT

Leader : H. Aoki (Japan)
Members : G. H. Tsohos (Greece)
R. Medeot (Italy)
T. Iwasaki (Japan)
L. Lefdal (Norway)
V. Cuéllar (Spain)
J. Santamaria (Spain)

Since the international survey done in 1991-92 covered disastrous events up to 1990,the Group is now conducting an updated questionnaire survey on recent road disasters since 1990. The new survey will cover the 1994 Northridge Earthquake and the 1995 Kobe Earthquake, and other major disasters worldwide.

The Group will revise the Comprehensive Report, while referring to the survey results and additional documents to be collect from G2 activities. The new version (to be published in 1999) will include lessons from recent road disasters, hazard potential assessment, new codes and guidelines, emergency planning and management, and so on.

9.3 HOLDING G2 SEMINARS

Leader : G. Pilot (France)
Members : All G2 Members

Several international seminars on natural disaster reduction for roads are organized by G2 Group for selected regions in disaster-prone developing areas. The seminars are devoted to decision makers and engineers working in the field of roads and road transport, who have to deal with natural disasters and their effects on highway infrastructures and road transport.

The seminars also address the effects of natural disasters that occur in many developing countries, such as landslide, earthquake, flood, avalanche, storm, volcano, etc.

One of the objectives of the G2 Seminars is to disseminate and exchange existing knowledge among experts from various disaster-prone countries. Information collected from the Seminars will be used in revising the G2 Comprehensive Report.

The First International Seminar was successfully completed in New Delhi, India, on January 29-31, 1997, with a great support of the Indian Organizing Committee (Chairman: A. K. Gupta, G2 Member). Keynote lectures, invted presentations and discussions were actively made under the following sessions:

1) Inaugural and Plenary,
2) Landslides,
3) Floods,
4) Volcanoes and Cyclones,
5) Earthquakes, and
6) Conclusions.

Some 150 experts participated in the seminar from 14 countries: 8 Asian, 5 European, and Cuba.

Scheduled programs for subsequent international G2 seminars are:
1) 2nd Seminar : For Mediterranean Countries, in May, 1998,
2) 3rd Seminar : For Latin American Countries, in 1998-1999.

Photo 1 PIARC G2 International Seminar in New Delhi, India (January, 1997)

9.4 REVIEW OF CODES AND GUIDELINES

Leader : R. Medeot (Italy)
Members: M. Okahara (Japan)
J. D. Cooper (U.S.A.)

Seismic codes and guidelines of bridges including the following will be reviewed:

1) CEN Eurocode 8, Part 2 (1994, Europe)
2) TNZ Bridge Manual (1994, New Zealand)
3) AASHTO Standards and CALTRANS Bridge Design References (1995, U.S.A.)
4) JRA Specifications for Highway Bridges (Japan, 1995)

The following key aspects will be overviewed and referred in the new G2 Comprehensive Report:

1) Design philosophy and performance criteria
2) Design seismic forces and site conditions
3) Analysis methods and analytical models
4) Design requirements, and
5) Future trends

9.5 STUDY ON EMERGENCY PLANNING AND MANAGEMENT

Leader : V. Cu éllar (Spain)
Members: R. Diaz (Spain)
To be nominated from Africa, Asia, N. America, Oceania, and S. America.

Emergency planning and management is a crucial aspect for mitigating road damage and resulting hazards caused by natural events such as landslide, earthquake, and flood. This group will collect, through the international survey, appropriate information on the following subjects, and compile the results in the G2 Comprehensive Report:

1) Laws and regulations concerning emergency situations
2) Emergency planning and disaster preparedness (pre-event and post-event measures)
3) Emergency management (lessons learned from actual road disasters)

10. CONCLUSIONS

PIARC Working Group G2 "Natural Disaster Reduction," began work in 1990, in response to the United Nations proposal on IDNDR. The G2 conducted various studies including a survey on road disasters, and published the Comprehensive Report [1] in 1995.

From the international survey it becomes apparent that landslide, earthquake, flood and snow avalanche are four major hazards, and that other hazards include volcanic eruption, tsunami, storm surge, strong wind, and wildfire. Road management executives should consider disaster preparedness measures against these effects on road safety.

Road management agencies should take proper disaster reduction measures to protect road networks from natural hazards. Disaster reduction measures can be classified into three categories: regular works, pre-event measures, and post-event measures.

Regular works include planning, design ,construction, and management, which are all important in reducing disaster. Pre-event measures may be:
1) Damage potential assessment,
2) Rretrofit work, and
3) Ddisaster preparedness.

Post-event measures may relate to two different phases: emergency measures (emergency survey and emergency operation) and repair work (temporary repair and permanent repair).

Road planners, designers, engineers, and management staff should take necessary actions regarding disaster countermeasures at each of their work stages. They should have ample knowledge of disaster countermeasures, including laws and regulations, pre-event measures, emergency organization systems, emergency operations, and temporary and per-manet repair methods.

It is also commonly recognized that development of better road networks that can provide detours in case of road blockades, improvement of post-disaster measures for proper repairing of damaged roads, and construction of safer roads are of great importance in promptly reopening traffic and saving communities attacked by disasters.

Exchanges of experiences and technical information on road disasters among various countries should be continued and enhanced, to make contributions to reduction of catastrophic life loss, property damage, and social and economic disruption which can be caused by natural disasters of roads and interruption of road traffic.

It is also recommended that road management agencies in disaster-prone countries consider preparing regulations and guidelines for dealing with natural disaster of roads and related structures, considering their own situations and natural conditions.

Finally the G2 Group will conntinue its work from 1996 to 1999, and publish the new Comprehensive Report in 1999, to distribute at the 21st PIARC World Road Congress to be held in Kuala Lumpur, Malaysia. During this period the G2 will focus on 4 topics:

1) International survey on recent road disasters worldwide, and revising the G2 Comprehensive Report,
2) Holding G2 international seminars,
3) Review of codes and guidelines, and
4) Emergency planning and management .

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