INSIGHT

BALANCED RISK ENGINEERING SOLUTIONS

Road & Highway Infrastructure

Understanding the Risk

Public infrastructure systems and facilities of a country or region are necessary for economic activity. Roads, highways, bridges, tunnels, and buildings (utility buildings and toll booths) must be protected and maintained to prevent or reduce loss from exposures of material damage and physical damage from natural perils of earthquake, flood, windstorm, snowstorm, volcano, tsunami, subsidence and collapse.

When evaluating road infrastructure, it is important to know the design standard, the quality of workmanship and history of inspection and maintenance. Roads, bridges and tunnels should be designed and built according to internationally recognized standards, such as the American Association of State Highway and Transportation Officials (AASHTO), or the BSI British Standards. Areas relative to the road infrastructure such as ponds, reservoirs, dams, railroads, and other physical attributes should also be considered.

Concrete pavement roads and highways should be evaluated based upon their location, use, weather conditions and geological exposures. Concrete pavements wear down largely from traffic, are subject to damage, wear from both traffic, and weather conditions. Various natural disasters such as earthquakes, windstorm, rain and flooding, tidal waves and volcanic activity affect road viability.

Maintenance is fundamental to concrete pavement road sustainability. Roads should be maintained as close to their original constructed condition as possible to preserve their capacity.

Vehicle loads, hard or soft shoulders, ditches, culverts, traffic flow, volume and speed limits are important conditions to consider when evaluating road longevity.

There are many hazards that cause damage to pavement road. Material from traffic can penetrates joints and cracks creating voids beneath that lead to water under the slab. Pavement holes can be caused by joint surface edges breaking due to freezing cycles and by the use of tire chains on the pavement. Expanding soil fill areas that have settled or a poor structural section of the road can cause settlement and road distortion.

Of natural disasters, the most prominent hazard to pavement roads from the standpoint of both frequency and damageability is the hazard of water. Floods cause water inundation that could wash road sections away. Heavy or long-lasting rain can wash away (erosion), unprotected or inadequately stabilized road sections. Roads located near bodies of water are also exposed to flooding and water damage. Ice can also cause damage to large sections of road due to weight, settlement, and strength during thaw. Earthquakes can cause surface rupturing and dislocation of the road.

Methods used in road design that reduce the risk of loss include road cuts and slopes, hard and soft shoulders, ditches, culverts, embankments, retaining walls, and longitudinal and transverse drainage systems.

Falling rock is a geohazard that should be considered in road design. Rockfalls are generally caused by water, freeze and thaw cycles, thermal changes, seismic vibration, wind, rodents, roots, blasting and other factors. Risk limiting solutions include rock bolts, cable anchors, concrete support, re-routing water runoff, energy absorbing nets and other methods. Up front geological engineering design and analysis, good construction and maintenance to spot potential problems should be in place to prevent rockfall incidents.

Tunnels should be evaluated according to the quality of the original design by reviewing "as built" construction records, rock support (lining), height clearance, length, traffic flow and volume, geological (soil inspection) studies, drainage, road, rail and proximity to surface infrastructure. It is important to understand the tunnelling support and lining systems. Tunnels should be provided with a ventilation system and emergency ventilation system that provides a means for controlling smoke. Factors to consider include tunnel location, length, height clearance, soil type, materials used for construction, presence of confined space, drainage, cross section and other details.

Bridges, or "highway structures", should be evaluated according to the original design criteria and construction specifications.

Structural elements should be assessed for deterioration. Consideration should be given to impact damage from vehicles, vehicles with heavy loads, damage to abutments, cracks in steel or concrete beams, abnormal conditions of trusses, impaired girders, deterioration of decks and joints, plugged deck drains, debris accumulation around abutments, loose bolts or fasteners, damaged or missing bridge rails or curbs.

Bridges are susceptible to collapse from earthquake wave phenomena by the harmonic motion it creates. Soil condition and liquefaction can also contribute to bridge collapse. Sustained heavy rainfall can cause debris basis to overfill and damage or wash out a bridge. Factors to consider in bridge evaluation include basic structure type, foundation, location, typology, length, span, foundation, and other details.

Infrastructure buildings, such as administration buildings, toll booths, mechanical rooms and electrical substations are provided for roads, tunnels and bridges. Contents of utility buildings can consist of electrical wiring, boilers, furnaces, air conditioning units, supply pipes, control panels, water supply pipes and other components of utility systems. Factors to consider for ancillary buildings include location, walls, roof, floors, floor area, stories and building use.

When considering damage from hazards to pavement roads, bridges, tunnels and supporting buildings, debris removal from whatever the cause of loss can be 50% or more of the total loss. Debris removal is difficult to quantify and not usually covered as part of a loss.

Related Loss Statistics

Catastrophic weather conditions can strike at any time. Losses from flooding, especially during heavy or long lasting rain, are one of the most serious hazards to roads, bridges and tunnels. The examples below illustrate the type of damages and loss of production that can occur as a result of flooding.

In late October and early November of 1998, Hurricane Mitch struck Central America, causing historic amounts of rainfall, causing major catastrophic loss to Honduras.

Damage was extensive causing bridges and secondary roads to be destroyed and wiping out over 70% of the transportation infrastructure. Crop losses were massive in addition to losses of livestock and in shrimp production. The banana industry was hard hit.

Due to the loss of road access, banana crops could not be shipped. This event was classified as a 1000 year event of which no engineering assessment could have predicted. Falling trees caused debris to collect in riverbeds in which flood levels were so high that they caused bridges to collapse.

On February 20, 2010, heavy rain and flash flooding hit Madiera, Portugal in the Regional Capital of Funchal. Rock slides blocked roads, storm drains were blocked, debris blocked riverbeds, streets and roads were inundated with water causing widespread damage. The airport was closed and bridges were washed out.

Structural inspections are critical to the integrity of a bridge. A bridge in New York collapsed resulting in loss of life and property. Flowing water scoured away the soil around the foundation which caused the collapse. This could have been prevented with regularly scheduled inspections.

Controlling the Hazard

A small physical property loss can create a large indirect and far-reaching loss. Inspections and maintenance are key factors to loss prevention. Maintenance regimens should be well documented. In some cases, maintenance programs are computerized.

Maintenance monitoring regimens fall into several categories: reactive, planned, predictive, corrective actions, remedial work (ongoing or planned), vibration monitoring of structures, and monitoring of earth movement and slope/ground stability.

In the State of Iowa in the USA a Department of Transportation crew found a significant crack in a girder on a steel span of a bridge while removing road salt. The crack was wide enough to fit in the blade of a knife. A possibly catastrophic loss caused by structural failure was prevented through an inspection program.

Concrete pavement deteriorates over time and requires preventive maintenance which is done to preserve the structure capacity of the pavement. Immediate maintenance is urgent repair that is carried out to maintain a roadway until it can be reconstructed.

Preventive maintenance is necessary to improve the structural capacity of the pavement. It is therefore important to have a complete understanding of the condition of the roadway when planning and designing all repair and maintenance programs.

Tunnels and bridges require repair and preventive maintenance to preserve the structures as close to their original condition as possible. Bridge repair is necessary maintain or replace the load carrying capacity of the structure. Tunnels must be maintained to protect concrete structure and linings.

Human Element

A design and construction program should be in place for new construction projects, and a review program should be in place to monitor existing roads. Infrastructure projects require oversight of many factors to ensure that loss potential is reduced.

New and existing roads should be evaluated for good construction design, workmanship, geological factors and through hydrology studies as well as assessment of the conditions of the surrounding the area.

Planned maintenance programs (Preventive Maintenance Program) are effective in preserving the structural capacity of roadways. Preventive maintenance programs are restricted to pavements that are in good condition. Guidelines for maintenance programs should be specific to the risk factors of the road type. Planned maintenance activities should be completed on schedule by well trained personnel.

Reactive maintenance programs should include activities designed to maintain a roadway until a construction program to reconstruct or rehabilitate a road get underway. An example would be to repair damage after a flood, earthquake or other occurrence of a natural peril.

A design and construction program should be in place for new construction projects, and a review program should be in place to monitor existing roads.

New and existing bridges should be reviewed for good construction design in accordance to international standards (AASHTO & BSI), workmanship, geological factors (soil conditions), topography, climate and natural perils and assessment of the conditions of the surrounding the area.

Bridges require removal of build-up on the structure, deck sealing, joint and bearing cleaning, maintenance of drains and caps, repair of load bearing capacity, beam replacement and repair of damage from vehicles (vehicle impact or high loads).

Tunnel structures require washing, drain flushing, snow and ice removal. Tunnels also require maintenance of fire protection and ventilation systems and gas testing.

Physical Protection

Physical protection for roads includes retaining walls and drainage systems. Bridges are provided with manual fire alarms, CCTV, culverts, drainage systems.

Tunnels require fire protection standpipe systems with adequate water supply, fire detection, communication systems, ventilation systems and drainage systems.

Ancillary buildings that support a bridge or tunnel should be of non-combustible construction. Buildings should be constructed in a location not subject to flood and wind damage and provided with appropriate fire protection systems

Key Risk Management Questions for Road Infrastructure

1. How is management interest in loss prevention rated?
2. What is the design age for the road, bridge or tunnel?
3. Were international design codes and standards followed?
4. What were the qualifications of the contractor, engineers and architect?

5. Have the construction documents (site plans) been reviewed and workmanship evaluated?

6. Was a geological study with soil investigation completed?

7. What is the earthquake zone? What is the history of earthquakes and natural perils of wind, flood, snow, tsunami, and others in the area of the infrastructure?
8. Has the road, bridge or tunnel had major damage that has been repaired?

9. What is the rating of the inspection and maintenance program? Is a budget provided for it?

10. Is the area subject to explosion hazard, burglary or sabotage?

RMC has a dedicated team of certified and experienced engineers with degrees, including those with civil engineering degrees to identify the full loss potential associated with road infrastructure risk. They will provide recommendations for design planning for new projects or improvement of existing infrastructure.

Additionally, RMC provides an inspection program, developed by structural engineers to provide an in-depth report of road infrastructure hazards and exposures as a benchmark assessment. This engineering team is available internationally and has knowledge and expertise in the application of codes and standards and in working with local authorities for road infrastructure projects. For more information, contact your **RMC** Risk Engineer

Reference

NFPA 502, *Standard for Road Tunnels, Bridges, and Other Limited Access Highways*, 2011 Edition

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