Earthquake: A Frightening Geohazard Phenomenon
Risk-Based Solutions Resources

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One of the most frightening and destructive phenomena of nature is a major earthquake and the devastation after effects such as collapsed buildings and fire. An earthquake is the vibration, sometimes violent, of the Earth's surface that follows a release of energy in the Earth's crust which has accumulated over a long period of time. The energy is usually generated by a sudden dislocation of a segment of the rock mass. Earthquakes can be caused by manmade events such as explosions, fluid withdrawal or injection into the ground, but these are relatively rare and usually controlled. The impact such as loss of life and property damage caused by an earthquake often reflects the size of the earthquake but is also related to the standard of infrastructures found in a particular village/town /city.

After seeing all the devastation caused by the Tsunami that resulted from an earthquake that hit much of Asia and many other parts of World, the question that comes to mind is how safe is the ground below our feet in Namibia? The answer is not a simple yes or no because it is complex and requires the understanding of the earth as a whole, the movement of various plates and the geological setting of Namibia. Therefore based on the geological setting one can say that Namibia may be relatively safe for our lifetime and for now, but things may change as the dynamic of the earth crust also changes over million of years. It hard for one to imagine that everyday, thousands of tremors (slight earthquakes) occur below our feet and the majorities are too small to be noticed. This is, because from a geological perspective, the earth is constantly changing, creating land and destroying land and these changes can affect any city/ town/village today. However, whatever the reason for an earthquake, one should remember that earthquakes do not kill people but poorly constructed and maintained infrastructure such as buildings do!

Earthquake Facts

An earthquake occurs when pressure causes rocks at depth to first bend and then, when the stress exceeds the strength of the rocks, break and snap to a new position. In the process of breaking, vibrations called seismic waves are generated. These waves travel outward from the source of the earthquake along the surface and through the Earth at varying speeds depending on the material through which they move. Some of the vibrations are of high enough frequency to be audible, while others are of very low frequency. These vibrations cause the entire planet to quiver or ring like a bell or tuning fork. The *focal depth* of an earthquake is the depth from the Earth's surface to the locality where an earthquake's energy originates (*the focus*). Shallow earthquakes have focal depths ranging from the surface to about 70 km. Earthquakes with focal depths from 70 to 300 km maybe classified as intermediate and the focus of deep earthquakes may reach depths of more than 700 km. The focuses of most earthquakes are concentrated at the junction of the crust and upper mantle which ranges from 40 km to 70 km. The depth to the center of the Earth's core is about 6,370 km, so even the deepest earthquakes originate in relatively shallow parts of the Earth's interior. The *epicenter* of an earthquake is the point on the Earth's surface directly above the focus. The location of an earthquake is commonly described by the geographic position of its epicenter and by its focal depth.

Our Knowledge on Earthquakes

Earthquakes and other natural geohazards, such as volcanic eruptions and flash floods, are all part of the geological knowledge pool that allows us to understand how the forces of nature operates. Today, seismographs, which are instruments recording the motions of the earth's surface caused by seismic waves are used in the study of earthquakes. Geologists have found that earthquakes tend to occur along faults which are zones of weakness in the Earth's crust. Essentially, faults maybe described as a crack in the Earth's surface where the rock has divided into two parts which move against each other. Most earthquakes are caused by a sudden slip along such fault. Stress mobilised from far distances such as the earth's outer layer pushes and then concentrate on the sides of a given fault. This results in stress building up to such an extent that the rocks on both sides of a fault plane slip suddenly, releasing energy in form of seismic waves. The seismic waves travel through the earth's crust and cause the shaking that we feel during an earthquake event. However, there is no guarantee that all the stress can be relieved during an earthquake event. This is so because relieving stress along one part of the fault may increase stress in another part of the fault and another earthquake could still occur. These are called aftershocks.

The key to understanding the likelihood of an earthquake event occurrences lies with having knowledge of the geological setting and the characteristics of faults. Even so, it is not possible to accurately predict when an earthquake will strike because it is a matter of time and being prepared! For instance, what do we know about Namibia and in particular the Windhoek area and other major settlements? The answer lies in the evolution and current regional geological setting of Namibia as well as the local geology of all the settlements including Windhoek. If we consider the whole earth, it has long been recognised that the earth is divided into several plates which move against or away from one another. Today there is evidence which indicates that at one time many millions years ago Africa and South America were joined but have moved away forming the South Atlantic Ocean. This movement continues to this day with the mid Atlantic ridges erupting volcanic material which forms the ocean floor. Most earthquakes occur along the plate margins and along the ocean ridges although some, about 10% do occur within plates.

Plates are segments of the outer rigid shell of the earth (lithosphere) that are internally rigid and move independently over the interior, meeting in zones of convergence and separating at divergence zones. There are three types of plate boundaries: spreading zones, transform faults, and subduction zones. At *spreading zones*, molten rock rises, pushing two plates apart and adding new material at their edges. Most spreading zones are found in the oceans for example, the South American and African plates are spreading apart along the mid-Atlantic ridge. Spreading zones usually have earthquakes at shallow depths which maybe within 30 km of the surface. *Transform faults* are found where plates slide past one another. An example of a transform-fault plate boundary is the San Andreas Fault, along the coast of California and north-western Mexico. Earthquakes at transform faults also tend to occur at shallow depths. *Subduction zones* are found where one plate overrides, or subducts, another, pushing it downward into the mantle where it melts. An example of a subduction-zone plate boundary is found along the northwest coast of the United States, western Canada, and southern Alaska and the Aleutian Islands. Subduction zones are characterized by deep-ocean trenches, shallow to deep earthquakes, and mountain ranges containing active volcanoes.

The African Plate is one of these dozen or more plates that are involved in a continuous motion, destroying and forming new land resulting in earthquakes, volcanic eruptions and mountain building. As plates continue to move, plate boundaries change over geological time and weakened boundary regions can extend into the interiors of the plates. A good example is the African Rift Valley which extends from the red sea through East Africa to Lake Malawi. It has even been suggested that this zone of weakness extends into Zimbabwe and Botswana (Okavango Delta). These zones of weakness within the continents can also cause earthquakes in response to stresses that originate at the edges of the plate or in the deeper crust.

Lets us now consider the geological setting of Namibia to understand the occurrences of earthquake within the country. The geological setting of Namibia consists of several cratons. A craton is portion of the continent that has not been subjected to major deformation for a prolonged time, hence less fracturing and less faults. These cratons cover much of the northern and eastern part of the country and in turn covered by thick geological materials such as sands, gravels and calcretes. Varieties of hard rock are found on the surface for much of the southern, central and north-central parts of Namibia. In these areas faults can be located relatively easy using a variety of mapping techniques. The majority of the faults found in these areas are well known to specialists involved in infrastructure development in these areas.

For instance, around Windhoek, the Pahl Fault is a well known geological structure that runs in the north-south direction more or less along Robert Mugabe Avenue, extending to the south towards Rehoboth, and to the north towards Okahanja. Smaller faults associated with the Pahl Fault are also found in most parts of Windhoek. Faults are relatively common and are found in all parts of Namibia. Although the majority of these faults are currently inactive, they were once active and probably they continue to cause small tremors that pass unnoticed.

It is also likely that the stress build-up along the fault plane is at a slow rate. However, building big structures on or the injection of fluids in such faults may accelerate the change in the stress state and cause localised tremors. Nonetheless, based on the geological setting of Namibia and the records of earthquake events, the country is relatively stable.

Faults and the Town Planning Process

A *fault* is a fracture in the Earth's crust along which two segments of the crust have slipped with respect to each other. Faults are divided into three main groups, depending on how they move. *Normal faults* occur in response to pulling or tension; the overlying block moves down the dip of the fault plane. *Thrust (reverse) faults* occur in response to squeezing or compression; the overlying segment moves up the dip of the fault plane. *Strike-slip (lateral) faults* occur in response to either type of stress, the blocks move horizontally past one another. Different types of faults are found in most parts of Namibia including urban areas. The ever increasing demand for housing, particularly in urban centres, is providing a challenge to find suitable ground conditions without faults for building construction. Urban land use planning is an excellent process, which if handled well with good effective policies, can be an instrument to the development of safe urban infrastructure. However, this process requires a complete understanding of the ground conditions on which all types of infrastructure are founded.

Unsuitable areas can be avoided or mitigation measures can be put in place if potential risks are identified before construction. The development of the Namibian Seismic Network together with other geological mapping tools such as *thematic mapping* can be used to study and locate faults that may have potential risks to sustainable infrastructural development. The knowledge from a seismograph network and thematic mapping can thus be transformed into policies, standards or minimum requirements for infrastructure development such as housing in areas with varying risk levels. This information can be represented in form of constraint or risk maps and used for planning purposes. Some of the other themes that can be included in a thematic mapping programme include the following:

1. A *Superficial layer* will indicate the properties of the various soft geological materials such as silts, sands and calcrete found on the surface.
2. A *Solid layer* will indicate the properties of the various hard rock outcrops such as granites, sandstones and schists as well as associated geological structures such as faults and rock contacts.
3. A *Geomorphology layer* showing all the geomorphic features such as scarps, river channels, flood plain and rock falls.
4. A *Constraint or Risk layer* showing all the constraints such faults, flood risk and solution holes that may have an influence on various infrastructural developments.
5. An *Opportunity layer* will indicate the infrastructural development opportunities in the different areas mapped and planned for development.

Aftermath of an Earthquake Event

The aftermath of a strong earthquake striking unprepared areas with poorly constructed structures located in unsuitable areas is often devastation. If the earthquake occurs in a populated area, it may cause many deaths and injuries and extensive property damage. Loss of life is usually caused by collapsed buildings, fire and drowning. Landslides triggered by earthquakes often cause more destruction than the earthquakes themselves particularly in topographically higher areas with unstable slopes. Earthquakes beneath the ocean floor sometimes generate immense sea waves called tsunamis. These waves travel across the ocean at speeds as great as 960 km/h and may be 15 meters high or higher by the time they reach the shore. For example, during the 1964 Alaskan earthquake, tsunamis engulfing coastal areas caused most of the destruction at Kodiak, Cordova, and Seward and caused severe damage along the west coast of North America, particularly at Crescent City, California.

Lesson Learned to Date

Earthquakes and other geohazards such as flash flood and landslides have and will continue to destroy property with loss of life. Until such time when mankind will fully obey the forces of nature and avoid building settlements in high risk areas or build appropriate structures to withstand earthquakes, history will keep repeating itself. However based on scientific data, probabilities can be calculated for potential future earthquakes or for that matter any geohazards such as a flash flood. Scientists can only estimate the probability of a major earthquake occurring say in the Windhoek area for a given number of years. In Namibia, and indeed in most parts of the world, technical knowledge on urban land use planning does exist.

However, it is important that this knowledge is taken a step further by developing and implementing relevant and effective policies/standards/minimum requirements for urban land use planning process and for the safety of structures. The focus should be on long-term mitigation of earthquake hazards (be prepared) by putting up effective policies on developable urban land and safety of structures, rather than hoping that one day a think-tank will develop an earthquake prediction instrument!