13th World Conference on Earthquake Engineering
Vancouver, B.C., Canada
August 1-6, 2004
Paper for Special Session on
Seismic Risk Reduction and Disaster Preparedness for
Major Urban Centers

THE 21 MAY 2003 BOUMERDES EARTHQUAKE LESSONS LEARNED AND RECOMMENDATIONS

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This paper is based on the author's investigation of the Boumerdes earthquake undertaken from 24 May to 2 June 2003 as a member of the Earthquake Engineering Research Institute's (EERI) (http://www.eeri.org/) post-earthquake reconnaissance team. The author is grateful to members of the EERI team who contributed greatly to his knowledge of the earthquake, and particularly to Prof. Madani Safar-Zitoune from the University of Algiers and to Dr. Omar Khemici from ABS Consulting in California who helped shape the content of this paper. Their input is greatly appreciated.

1. Introduction

The magnitude 6.8 Boumerdes earthquake of May 21, 2003 shocked the Algerian nation by the extent of its human and financial losses. Yet, the earthquake should not have been a surprised neither by its occurrence, nor by its impact. The coastal region of Algeria and particularly its central section is known to be part of an active tectonic structure where the African plate collides with the Eurasian plate. This collision naturally releases its internal strain through the occurrence of earthquakes, which in such a tectonic environment tend to register large magnitudes (Morell & Maghraoui, 1996). Historically, several large earthquakes have occurred in the Algiers region in the past, including the great earthquake of 1716 earthquake, which destroyed the city of Algiers and caused more than 20,000 fatalities at that time. Several more moderate earthquakes have occurred in the Algiers vicinity in recent years (Benouar, 1996). Pushed by a high demographic rate and by an influx of migration towards the cities, the Algiers region has grown significantly in the last decades. The heavy demand on housing combined with lack of regulatory oversight resulted in a disparate and often uncontrolled real-estate market (Safar-Zitoun, 1997). The adequacy and applicability of seismic safety standards was not systematically applied in construction practice, thus putting a large inventory of buildings at risk from earthquakes. The vulnerability of the building stock is aggravated by the large inventory of pre-seismic standard buildings from the colonial, which have proven to perform poorly, even under moderate earthquake ground motion. Hence, the exposure to earthquakes was predictably high in the region both through its seismo-tectonic environment and through the vulnerability of the building stock (Bendimerad, 2000a). This vulnerability is compounded by a weak state of preparedness of the Algerian society and institutions, and a lack of a culture of prevention among civil society.

While the region and the country are still recovering from the impact and the trauma of this event, it is important to draw the lessons and suggest recommendations so that such the mistakes of the past would not be repeated in the future.

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These lessons and recommendations are framed within the premise that there is a set of factors that determine social and material vulnerability of communities in developing countries, and thate only way to reduce the impact of earthquakes is through an engagement of the institutions (both governmental and non-governmental) and civil society into active preparedness and mitigation. Government should allocate the resources, set the policies, commission studies, enact legislation and develop programs that take away the unknown character of earthquakes and turn them into parameters for planning and mitigation. At the same time, civil society should play its role in developing and nourishing a culture of safety. Resources should be committed to ensure long-term sustainability so that such efforts carry their fruits to the future generations. However, many developing countries do not have the resources (human, financial, technical) to make this transformation on their own and will require support from the international community at many levels. The lessons and recommendations are generic and applicable to many developing countries.

2. Unsustainable Development and Unsustainable Risk

The increase in the cost and frequency of disasters is the direct result of human action. Disasters are not natural phenomena; disasters are directly correlated to development. Human development increases societal vulnerability to natural and man-made hazards. It impacts both the frequency and severity of disasters, increasing the susceptibility of population and impairing sustainable development. Unplanned and ill-planned urbanization has been the cause of environmental degradation (e.g., deforestation), overexploitation of natural resources (e.g., water), ecological disturbances (e.g., pollution), and social destitution (e.g., increase of poverty), which are all factors that convert natural hazards into disasters. Demographic pressure results in higher vulnerability of population to natural hazards through increased concentration of population in substandard living conditions, increased vulnerability of the build environment caused by shoddy construction, and increased fragility of socio-economic systems caused by land-use and urban development practices that do not account for the susceptibility to natural hazards.

In developing countries, where rapid urbanization is taking place and where the process of urbanization is often uncontrolled or poorly controlled, societal vulnerability to earthquakes and other disasters keeps increasing alarmingly. An estimated 97% of natural disaster-related deaths occur in developing countries and economic loss (measured as a fraction of Gross National Product) is about tenfold larger (World Bank, 2000). Ninety percent of the global population growth is taking place in the least developed countries, which do not have the capabilities and resources to adequately plan and manage the high rate of urban growth. By 2010 eight out of ten largest cities of the world will be in developing countries. No less than seventy of the hundred most populous cities in the world can expect, on average, a strong earthquake at least once every fifty years (ISDR, 2002). United Nations statistics indicates that in the 1990's close to 70% of the construction in the developing countries was build illicitly. Illicit construction contributes greatly to the increase in disaster exposure in developing countries.

The metropolitan city of Algiers is a typical example of rapid, often uncontrolled development, which has continuously increased its exposure to earthquakes and other disasters. In the Algiers region, statistics indicate that as much as 50% of the construction is build without proper authorization, legal ownership documentation or a building permit. Construction control for private construction is for all practical purposes inexistent, and public awareness about basic earthquake safety is rudimentary. These conditions have made Algerian cities and particularly the Algiers region highly vulnerable to earthquakes. Drastic and sustained measures are needed in order to reverse the process of risk inflation by implementing planned pro-active risk management actions (Bendimerad, 2000b, 2003).

3. Urbanization Factors of Vulnerability

a. Lessons Learned

- The rapid and in many cases uncontrolled urbanization of the Algiers metropolitan region has contributed to the vulnerability of its communities and its infrastructure. The Boumerdes earthquake has shown that a formal and planned real-estate market produced relatively well-structured and stable communities in cities such as Boumerdes and Reghaïa, but informal mechanisms, on the other hand, have resulted in less stable and mostly more vulnerable communities on the outskirts of Algiers.
- Opportunistic access to land coupled with uncontrolled construction significantly increased the vulnerability as demonstrated by the heavy human and material losses in this earthquake. Poorly planned and constructed communities sustained more losses than well-planned ones. Much of the damage must be understood in the context of rapid, increasingly vulnerable urbanization.

b. Recommendations

- The process of urban planning should incorporate hazard factors as determined from zonation studies. The sitting protocols should take into consideration potential for fault rupturing, soil instability and soil amplification.
- Most importantly, enforcement procedures and regulations should be put in place to enforce the architectural and urbanization requirements that are developed in the state planning organizations. That includes enforcement of requirements for sitting, building separations, building height, and use of building material. Since local jurisdictions are administratively responsible for the development of requirements for urban planning and land use planning, they should be provided with resources and capabilities to adequately perform these tasks. This can be accomplished through training and professional development of technical staff but also through regulation that provides more capabilities but also more accountability locally.
- Providing transparency in the administrative processes required for land acquisition, land ownership, and property ownership would reduce human intervention and potential corruptive practices.
- Detailed vulnerability studies should be undertaken for major cities. These studies should provide the elements for mitigation and preparedness. A disaster management master plan should be developed for each of these cities.
- Gaining a better understanding of how urbanization and development affect earthquake vulnerability, especially in terms of providing stable communities by formalizing the process of land and property ownership and respect for building regulation such as access to building permitting and building occupancy.

4. Socio-Economic Factors of Vulnerability

a. Lessons Learned

- The earthquake strengthened social links in communities that were stable and more unified and weakened them in communities that were individualistic and less structured.
- The earthquake has broken several stable social links, and new links may take years to develop. As demonstrated by previous urban earthquakes, social trauma may be difficult to

assess and attended to, especially among the less privileged portion of society such as the old, the children and the poor.

- In the post-earthquake environment, polarization develops between the victims who had legal ownership of their property (i.e., duly recognized by government officials), and those who do not have legal ownership of their properties. Interestingly, this legal characteristic of the victims is not related to poverty since those who built illegally often had material means and social influence. While the more formally organized communities will likely have an advantage negotiating through the bureaucratic process, past experience has shown that individuals can also influence and disturb governmental action. The political and social stakes are high in the decisions required for re-housing the population.
- This earthquake highlights an observation from recent urban earthquakes that post-earthquake housing is a major issue, requiring attention prior to the event and creative problem solving after an earthquake. The loss of large number of dwelling contributes to a social instability that may remain for years after the earthquake. This situation is not specific to Algeria and to the Boumerdes earthquake in particular. Recent urban earthquakes such as the 1995 Kobe earthquake in Japan, the 1999 Marmara earthquakes in Turkey, and the 2001 Gujarat earthquake in India remind us of complexity in re-housing and relocation issues. More than four years after the Marmara earthquake, many victims are still living in temporary housing and several issues related to re-housing and compensation have yet to be resolved. It took the government of Japan five years to settle the housing issue for the victims of the 1995 Kobe earthquake. Despite the government-institutions' willingness to resolve this issue of re-housing in expedite manner, experience has shown that these issues can have lasting effects.
- The issue of financing losses from earthquake and other catastrophes must be addressed. Earthquake insurance is for all practical purposes inexistent in Algeria. The Algerian government will assume the overwhelming portion of the losses from the Boumerdes earthquake. These funds will be diverted from economic development programs and from basic social services. This is not necessarily the best policy considering that disasters are frequent in Algeria. The issue of financing the cost of disasters remains to be resolved.

b. Recommendations

- Several studies related to the social aspects of the earthquake needs to be undertaken. It is important to understand how the losses have impacted families and communities and how the social structures have performed under the stress of the earthquake. Studies should assess the need to respond to the long-term social trauma and its consequences on community health and civic performance.
- Studies should also be undertaken to assess the socio-economic impacts of re-housing of population and the development of least disturbing processes for relocation. Authorities responsible for re-housing should look at experiences in other countries that have been going through this process.
- The government has announced the creation of a mandatory earthquake insurance system. Such system exists in many countries, and has, in many cases proven efficient in providing a means to finance catastrophe losses. However, one needs to be prudent that such a system does not just become an additional financial burden on homeowners.

5. Emergency Response

a. Lessons Learned

- The earthquake response was in general fairly efficient due to the high state of readiness of the security agencies, but was also facilitated by the good performance of the transportation systems, which did not fail and allowed easy access to the disaster areas.
- The immediate response in the first hours after the earthquake was done by the local communities who did not the training and necessary equipment to remove the heavy debris.
- International standards (e.g., SPHERE) were not systematically respected in the development of the temporary infrastructure (e.g., tents, sanitation, etc) to take care of victims needs.
- Government response plans (ORSEC plans) proved to be outdated because they have not been kept current to reflect the administrative and social realities.

b. Recommendations

- Routine earthquake simulations should be performed by the Civil Protection authorities to determine the adequacy of the search and rescue plans. Response plans should be developed to identify the resources needed to respond to a disaster. These resources include both the human potential as well as the availability of heavy equipment, which hindered the immediate intervention of search and rescue in Boumerdes.
- Emergency response plans should recognize that for the first several hours after an earthquake, the first response is going to come from the local communities. Hence, training programs involving local volunteers are important to reduce the life loss from an earthquake.
- Drills should be undertaken to test the emergency response plans and keep them current with respect to changing conditions.
- Quick and acceptable solutions for interim housing and replacement housing need to be researched prior to an event so they can be implemented quickly.
- Governmental institutions and civil society organizations should adopt policies and develop programs for pro-active preparedness and mitigation instead of being concerns by response only. Awareness programs, preventive actions and long term mitigation policies will result in more responsible and capable institutions, more engaged communities and a more aware civil society. Urban risk reduction must be viewed as a partnership between the government and its citizenship.
- GIS based simulation models should be developed. Such models would allow emergency managers to quickly estimate location and extent of damage to lifeline systems, essential facilities, chemical facilities with hazardous materials, high density population areas, etc. This knowledge will allow an appropriate speedy response to the neediest areas, which will translate in a reduced loss of life.

6. Hazard Factors of Vulnerability

a. Lesson Learned

- The Boumerdes earthquake demonstrated that the basic seismological and geological parameters for quantifying the earthquake hazards to the region were unknown or poorly known. The earthquake hazard was grossly under-estimated. While, the Algerian

earthquake code prescribed design values for buildings in the order of 15% gravity, there is evidence that in the epicenter region both the horizontal and vertical accelerations from the earthquake exceeded 100% of gravity. In an active tectonic environment such an underestimation could have been trivialized by undertaking some basic geoscience research. Indeed, a portion of the damage to the buildings may have been saved had the design requirements be commensurate with the seismic exposure of the region.

- Soil and site effects were often not included in design of buildings.

b. Recommendations

- A comprehensive understanding of the earthquake hazards in northern part of Algeria is still lacking. In particular, the nature of the plate margin offshore of the Algerian coastline should be mapped and studied. Similarly an investigation of the historical seismicity of the country and its relationship to the tectonic environment should be undertaken. Currently, the nature of risk to the city of Algiers itself is of up most importance. Similarly, risks to other major cities such as Oran are also very high. However, the critical information to understand the earthquake hazard is for most part unknown. For example, the issue of the potential increase in the likelihood of an earthquake in Algiers due to the stress migration from the Boumerdes earthquake cannot be answered without an understanding of the offshore fault structures (Stein, 1999). Similarly, an adequate level of earthquake design for the region cannot be determined without an accurate earthquake hazard mapping.
- Risk assessment should be recognized as an essential tool for understanding risk parameters and contrainst and for promoting risk mitigation. Further risk assessment is an instrument for risk communication and education allowing stakeholders to understand their risk, the options for dealing with it, and also to participate in the decision-making process.
- Geotechnical parameters should be taken into consideration in new construction. Other effects such as near field conditions and directivity should also be introduced in the design procedures.

7. Design and Construction Factors of Vulnerability

a. Lessons Learned

- The vulnerability of the housing stock has been fully demonstrated in the Boumerdes earthquake. While the vulnerability of the old construction was well documented and raised concerns in the past, the Boumerdes earthquake illustrated that newer construction, particularly individual housing built within the last decade, was also at high risk. A disproportionate fraction of the damaged housing was in single-family houses built of reinforced concrete frame with hollow brick infills. Such type of structures is demonstrated to have poor performance in past earthquakes if not designed and constructed properly.
- Some types of structural systems performed well including shear-wall type buildings (particularly, tunnel formed shear wall buildings), steel frame buildings with lightweight partitions, and precast concrete structures with monolithic joints.
- Some industrial facilities (SNVI, grain silos) and public work facilities (dams, ports, airports, and water tanks) sustained severe damage causing business interruption losses. Transportation systems generally performed satisfactorily in comparison to the housing stock
- The earthquakes also demonstrated the vulnerability of essential and critical facilities, such as schools, hospitals. The education sector was hard hit by the earthquake and calls into

question the design and construction of schools, hospitals and other critical facilities in Algeria.

- Aging and vulnerable lifelines and weak public buildings contribute to heavy losses, and complicate the ability to respond and recover quickly.
- Lack of construction controls, code implementation and code enforcement is a major cause for damage. In Algeria as it is the case for many developing countries, seismic codes exist but there are not implemented. Poor construction quality endangers communities and aggravates the losses from earthquakes and other hazards. Currently Algeria (and many other developing countries) does not have the technical capacity to systematically implement the building code requirements. But several initiatives can be undertaken to ensure that in a few years a construction quality and control program is in place in the country (see recommendations).
- The issue of repairs and strengthening of the damaged buildings create a significant challenge for post-earthquake recovery. In front of the logistical and financial issues associated with taking care of such a large number of damaged buildings, the technical issues may get over shadowed. Repairing and retrofitting damaged buildings is a complex and challenging technical problem in many developing countries. Despite the urgent need to provide housing to the displaced populations, the repairs and retrofit of damage buildings must be accomplished to acceptable standards. There is an urgent need to put many of the damaged buildings back in commission. However, one must stress the complexity in providing competent repair and retrofit techniques and warn against hasty approaches that could provide a false sense of safety while wasting valuable resources.
- Undoubtedly the biggest issue facing Algeria and other developing nations is the abatment of the risk caused by the existing building stock that is vulnerable to earthquakes. In Algiers, the inventory of weak and vulnerable buildings numbers thousands of buildings. The vulnerability of such buildings has been demonstrated in each earthquake. In addition, many of these buildings also have soft stories that aggravate their vulnerability to earthquakes. The current state of degradation of some of the old housing stock is by itself catastrophic. Yet, this issue cannot be ignored.

b. <u>Recommendations</u>

- Introducing minimum safety standards for new building construction can reduce the risk from future earthquakes. In particular, improvements in the design and construction of reinforced concrete frame buildings with brick infills, which is a very prevalent and very vulnerable type of construction in Algeria is urgent and vital in order to reduce the increase in risk. Knowledge for building ductile reinforced concrete structures is available since the early 70's, and yet highly vulnerable reinforced concrete frame structures continue to be built in large numbers everywhere in Algeria.
- In view of the quality control requirements demanded by concrete frame buildings, it may prove more beneficial to simply adopt shear wall type construction, especially for multi-story buildings (3 stories and above).
- Clear guidelines should be provided for the construction of brick infills.
- Seismic code provisions should extend to single-family homes, which sustained a large proportion of the human and economic losses during the earthquake. Typical family housing tends to be fairly massive and, hence is not trivial as far as it design and construction.

- More stringent seismic requirements should be imposed on critical facilities and high occupancy facilities such as schools, hospitals, police and fire stations, airports, auditoriums, and others. Designs should be submitted to third party reviews and site controls should be performed to make sure that construction is conformed to design.
- Industrial facilities critical to the economic welfare of the country should also be designed to higher standards. Existing critical facilities such as power stations, refineries and others should be evaluated for safety and performance.
- A long-term effort should be undertaken to provide a nationwide capability for code implementation and for good construction practices. The first step in this process consists of a systematic training program for engineers, architects, contractors and other construction professionals so that they can undertake control functions in their practice. Similarly, earthquake-engineering courses should be introduced in the university curriculum for civil engineers and architects. A licensing process should be put in place to make sure that designers and contractors have the necessary knowledge of fundamentals in earthquake resistant construction. Finally, regulation should be introduced to institutionalize construction control and to provide the necessary resources for developing a quality control process in the country in the near future. Regulation and enforcement mechanisms should encompass both the private and public sectors.
- Meanwhile, government authorities can introduce a system of third party checking of design and construction as well as enhance the capabilities of CTC ("Control Technique de Construction").
- Ultimately, only licensed professionals should be allowed to engage in the design and construction of critical facilities and in structures whose failure could have life safety consequences.
- A long-term approach should be taken in addressing the problem of retrofit of existing vulnerable structures. Future losses from earthquakes cannot be reduced without addressing the abatement of the risk to the existing buildings. The two largest cities of Algeria (i.e., Algiers and Oran) are most at risk. Issues related to retrofit of existing buildings are very complex and involve more than just technical issues. The social, economical and legal issues related to seismic retrofit of existing buildings are complex and can be overwhelming. The technical approaches are also not trivial. A long term view that allows retrofit to get integrated with urban renewal programs and can provide the incentives for building owners to undertake retrofitting may show more success. New regulation may need to be introduced to resolve decision process in co-ownership properties, and to provide incentives for seismic retrofit. The concept of disaster management master plan advocated by the author previously for managing the risk to Algiers and Oran should be considered. Examples from other countries should be closely analyzed. In particular, the experience from the Municipality of Istanbul in Turkey could be highly valuable for the Algerian authorities.
- A strong argument can be made against spending valuable resources in retrofitting buildings in Boumerdes, and to shift these resources instead to the older neighborhoods of Algiers and other highly exposed cities such as Oran, where the likelihood of occurrence of an earthquake is much larger than a repeat of an earthquake in Boumerdes. It would probably take centuries for a repeat of the Boumerdes earthquake to take place, whereas other highly seismic areas are much more prone to an event.
- The state-of-the art in repairing damage buildings is not well established. In the context of a country such as Algeria, where the structural engineering resources and training are very

limited, there is ample room for mistakes and for loss of valuable resources. There is also a possibility for a loss of opportunity in terms of making sure that the repaired buildings are competently strengthened so that they do not get damaged in the next earthquake. It is important to establish a design and construction control process and to benefit from the experience of other countries (e.g., Turkey or India) that had to deal with similar issues under similar circumstances in recent years.

- Survey of building damage by construction type, year of construction, height, extent of damage, failure mode, estimated ground shaking, soil type, etc. Such studies would identify potential improvements to make in the current seismic code. These studies would provide vulnerability data that could be could be useful in the vulnerability studies of other cities in Algeria and elsewhere.
- Strengthening lifelines and public facilities should be included in the urban mitigation agenda of governmental and non-governmental agencies in charge of lifelines and public facilities, especially for power and water distribution systems.

8. Conclusion

The challenges facing the Algerian institutions and the Algerian civil society are reminiscent of the post 1980 El Asnam Earthquake. Significant earthquake mitigation planning and initiatives took place following that earthquake, which gave Algeria at that time a significant lead in the understanding of earthquakes and their impact. However, the post-El Asnam momentum faded away only a few years after it started, and the full benefit from that effort was not harvested. Social and political transformations shifted national focus and government priorities towards other pressing issues. Meanwhile, urbanization, aging building infrastructure, societal pressure, and unprepared institutions have increased the exposure to disasters, weakened the resiliency of communities and made them more vulnerable.

This is a typical pattern in many developing countries. Disaster risk reduction requires a long-term approach and sustainable actions. The human potential of many developing countries is grossly under-utilized. For example, the intellectual capacity of the universities and research institutions seldom get put in place to participate in the process of development and disaster risk reduction. The capacities of individuals and institutions have to be put together in a collective effort to undertake the challenges of dealing with reducing the vulnerabilities from earthquakes and other disasters. The currently disparate resources (human, institutional and financial) should come together to deal with the challenging tasks ahead.

A country's disaster reduction agenda should recognize the basic premise that human intervention designed to reduce vulnerability of communities and their assets reduces their exposure to disasters. The correlation between human development and disasters is now well accepted. Thus, disaster risk reduction should be integrated as an explicit component of developmental and environmental programs at the national, regional and local levels. In view of the potential catastrophic human and economical costs of future earthquakes, governmental and non-governmental institutions must adopt a more aggressive attitude towards disaster risk reduction.

The chances for success depend on a major shift in collective attitude where compromise is set by refusing to compromise on the common responsibility, and by requiring accountability while offering transparency. The standards of responsibility of government should be set higher than where they stand now. The notion of protection against avoidable risk should be promoted and accepted as a basic human right. A government's first responsibility pertains to the protection of its citizens and institutions. The challenge of reducing vulnerability to earthquakes and other disasters requires more than the passive acknowledgement of problems; it entails a commitment from government, public institutions, and civil society to a sustained effort of disaster risk reduction, by supporting vulnerability reduction programs and

building a culture of prevention in the country. The process of urbanization cannot be stopped, however, knowledge does exist to build earthquake resistant buildings and protect communities from unnecessary risk to their lives and property. Community preparedness efforts and prevention and mitigation policies can increase resiliency and decrease vulnerability to future events.

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