

Reflexions on multidisciplinary and geologic risk management in Cuba

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ABSTRACT

Geological risk management has special relevance in construction and the creation of new infrastructure in Cuba. The aim of this work was to focus on making some reflections about the multidisciplinary analysis of geological risk management in the country from a critical perspective

Keywords: management, multidisciplinary, geological risk, construction, infrastructure.

RESUMEN

La gestión del riesgo geológico tiene una especial relevancia en la construcción y la creación de nuevas infraestructuras en Cuba. El objetivo de este trabajo fue centrarse en hacer algunas reflexiones sobre el análisis multidisciplinario de la gestión de riesgos geológicos en el país desde una perspectiva crítica.

Palabras claves: gestión, multidisciplinariedad, riesgo geológico, construcción, infraestructura.

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Introduction

Geological events affect the disordered way that man has set into space, on many occasions and for various reasons, in terms of maximum exposure and high vulnerability to natural phenomena's whose potential levels are known, thereby creating very high-risk situations. Its prevention at national, regional, and local levels could be solved applying policies, measures and actions that can be implemented within the investment process that is executed for the construction of new infrastructure. The possible occurrences of earthquakes, flooding, landslides, erosion processes, and action of the sea on the coasts among others, constitute hazards whose impact can lead to serious injury or geological risks.

Geological risks form part of a wider range of environmental risks and are grouped into classes according to their origin. The definition of geological risk has been addressed by several authors; one of its first definitions was made by the US Geological Survey in 1977, stating that geological risk is understood as any geological condition, process or event that involves a potential risk to the health, safety or welfare of a group of citizens or for the functions of a community or economy (Brusi-Roque, 2003). Another definition understood them as a circumstance of distress, loss or damage to social and economical development due to a geological condition (Ogura and Soares, 2005).

Man's interaction with the environment creates potentially hazardous situations since human action itself triggers mechanisms involving natural hazards, or natural geological events may constitute a danger or lead to

social harm. Some of the most comprehensive geological risks conception posed them as those processes, events or situations occurring in geological environments that can cause damage or harm to communities or infrastructure occupying vulnerable territory. They can also be understood as any geological, natural, induced or mixed situation or event which can produce economic or social harm to a community, where geological criteria may be used for their prediction, prevention or correction (Ayala, 1992).

Management is thus needed to avoid or prevent such geologic risks, a concept bringing together issues such as study, planning, organisation, evaluation, management, analysis, implementation, monitoring and control (Koontz and Weihrich, 1998). This is an element which when properly inserted in terms of geological risk mitigation is a very useful working tool regarding construction and infrastructure. Geological risk management concerns studies regarding phenomena or processes related to geodynamics and earth processes or phenomena induced by human activities affecting projects and/or civil engineering works, or infrastructure, situated or in the future be located on the ground, so that they contribute towards planning, organising, directing, evaluating and controlling organisational, technical and technological measures for such projects or works, aimed at preventing or mitigating the effects of disasters caused by natural or man-made geological events (Galban, 2010).

The main problem of international risk management for all levels of government is that risk management is a long-term problem and governments have not been particularly good at planning long-term development and have not spent much money on reducing such risks to long-term



Figure 1. Diagram showing the interrelationship of factors involved in geological risk management.

(Monge Granados, 2003). Governments have a crucial weakness regarding risk management; specialists also play an important role here but similarly have not demonstrated their expertise in this area.

This analysis indicates that there must be a proper multidisciplinary relationship between specialists, government and the community (Figure 1); such interaction influences such actors to a greater or lesser extent regarding geological risks concerning man-made structures and therefore whether risks will materialise, meaning that management needs to be contextualised, proposing a mechanism that permit each country working according their real possibilities.

Cuba, the largest island in the Caribbean, is not an isolated case. Here, the multidisciplinary management of geological risks developed during construction process deserves an independent analysis according to its singular political and administrative system.

Data and methods: the Cuban experience referred to the multidisciplinary management of geological risk

A summary of the bibliographic sources consulted has described *multidisciplinarity* as being cooperation between different disciplines towards common goals, whether related or not, where there can be coordinated collaboration from the exchange of ideas to the mutual integration of basic concepts and methods aimed at providing solutions and establishing a foundation for such solutions.

Multidisciplinarity in environmental management and therefore in geological risk management has a close relationship with *decision theory* which has been studied extensively in the field of economics and engineering science. The methods used today are the product of research in such areas of knowledge.

It is undeniable that every real decision is in fact a compromise between different solutions, each having its own advantages and disadvantages, depending on the position to be adopted (García Layton, 2004). As in economics, agriculture, industrial engineering and social sciences, decision theory is a necessary tool in geological science applications, particularly in geological risk management regarding construction and infrastructure where specialists from different institutions are involved, including construction, architectural design, projects, scientific institutions specialising in implementing geological projects, geotechnical studies, physical planning and government.

Multicriteria decision-making, or adopting a multidisciplinary approach, involves predicaments in business and public administration; it is difficult to make a decision regarding a public issue (such as geological risks) that will satisfy all stakeholders, because the cost often comes into conflict with other criteria. However, multidisciplinary analysis has to prioritise realism and readability which are important assets in organisations, at a time when the complexity of decision-making is recognised by most actors, even if not all of them show the same sensitivity regarding the different criteria.

There have been experiences of international multidisciplinary participation and choices being made to reduce geological risks regarding construction and infrastructure; the most commonly seen have been in implementing preparedness, prevention and mitigation so that damage caused by geological events involving construction has been minimal and that rehabilitation and reconstruction efforts have enabled lower costs, as suggested by World Health Organization/Pan-American Health Organization (WHO / PAHO) since 2000 regarding management and comprehensive disaster management (Figure 2).

Disaster management is supported by the body of knowledge, measures, actions and procedures, which together with the rational use of human and material resources are geared toward the planning, organizing, directing, implementing and monitoring activities to prevent or reduce the effects of disasters on people and infrastructure services and products. The actions and tasks performed for the management or disaster management are permanent in time and space, forming a cycle comprised of three phases: 1. Before (Prevention, Preparedness and Early Warning), including measures and actions designed to prevent or reduce the disaster, among these are:

- Conduct ongoing monitoring and surveillance of natural and human phenomena through information systems and early warning systems interconnected to the a main center.
- Liaise with all systems generating information on natural hazards and anthropogenic (human induced) that loom over the town or the country in general.
- Disseminate information in a timely and necessary regarding disaster prevention and care among institutions, authorities and general population.
- Conduct or processed information sharing between institutions involved in advance in the prevention and relief of national and international levels.



Figure 2. The cycle for managing and integrating disaster management. WHO / PAHO 2000.

- Investigate, evaluate and analyze natural and human phenomena that can lead to disasters.
 - Develop tools for the analysis of risk factors that facilitate the process of national planning and land use in conjunction with relevant agencies.
 - Apply risk reduction measures in buildings and general infrastructure to minimize possible damage.
2. During (Response) formed by the set of activities and measures used during and immediately after a disaster to minimize its effects, the work also includes rescue, search and rescue.
3. After (Rehabilitation and Reconstruction), consisting of actions to the state's recovery after the disaster, where in addition (and as part of the development process) again begin to apply the measures provided for in the first phase.

As said before, the occurrence of geological phenomena's could lead to a disaster and there for management is needed. Elements related to the management of geological risks regarding construction and infrastructure in Cuba become particularly relevant during the initial construction/investment stages. Reviewing the pertinent literature on these issues related to Cuba confirmed that several actions had been taken aimed at multidisciplinary analysis concerning geological risk management, especially concerning intervention by legal regulations established in Cuba regarding aspects such as obtaining an environmental license, compatibility with defence, micro-localisation studies and the authorisation of technology.

Although Cuba has made progress regarding the above, especially when compared to the rest of Latin-America and many other Third World countries, difficulties do remain. The trouble lies in its effective implementation; there is the need for specialists having different skills to those of the architects, civil and hydraulic engineers and geologists (who mainly work in construction) who become involved in research, ultimately contributing with important elements to key project decision-making. There is the obligatory preparation, study and search for information by specialists working in the construction industry regarding geological risks, a very necessary process today which is facing palpable weaknesses.

Specialists (most often lacking construction expertise) from other branches of industry which are not related to construction and hydraulics express opinions on issues related to environmental risk management every day. Such situation needs to be ordered; the necessary criteria and intentions exist and Cuban law regulates such matters in an organised and

harmonious way. Its achievements in this field demonstrate such statement, only the multidisciplinary integration tools are missing.

Multidisciplinary action is legally pre-designed regarding construction/investment in Cuba. Ministry of Economics and Planning Resolution 91/2006 "Notes on investment" Article 3, Section 4, deals with "Integrated Project Management" for promoting multidisciplinary work; however it is not clear from the geological point of view exactly which action can be implemented.

The resolution states that an investor must, "hire other subjects to participate in investment to maximise its comprehensiveness", or, "construction requires guarantees during different investment stages", but does not consider how or what methods will be used to achieve such integration, or whether to invite or hire different specialists from institutions providing such guarantees (environmental licence, compatibility with civil defence interests, the use of technology, etc.), when it comes to making key decisions regarding the mitigation of geological risk. Actions such as integrating risk analysis, multidisciplinary team decision-making and reconciling views with organisations, specialists, society and policy-makers are all elements that help decision-making and therefore better geological risk management.

The Cuban government is taking action to this end, even though this is still insufficient; the integration methods used are not always the most appropriate ones, resulting in problems regarding geological risk management. Results could be even better by applying multicriteria principles (i.e. the multidisciplinary approach proposed here), placing greater emphasis on infrastructure and construction.

Cuban environmental law is governed by the Ministry of Science, Technology and the Environment (CITMA) (Law No. 81/1997). This ministry has worked on environmental issues and risk management in Cuba, issues which have been well reflected and identified in its national strategy. The agency has issued some regulations influencing geological risk management involving multidisciplinary, the key one being Resolution 77/1999. This resolution contains the regulations stipulating how to apply for an environmental licence (essential for starting construction work). Multidisciplinary participation involves several institutions in obtaining an environmental licence; the National Seismic Research Institute becomes involved concerning geological risk management, carrying out investigation and designing some national standards, such as the Cuban Earthquake Resistance Code and geotechnical standards.

Resolution 77/1999 dealt with geological risk management during a project's initial stages or planning. If significant, initially unforeseen negative effects arise during the implementation or exploitation of work, the authority could order the cancellation or suspension of the environmental licence regarding the draft work or activity. This implies an immediate halt to the work or project (Resolution 77/1999, Article 20).

Civil defence guidelines have been determined in Cuba through regulations and state plans, i.e. National Defence Law 75/1994 and Decree 262/1999 "Regulations for harmonising the economic and social development of the country's defence interests." The latter provides for a judgement to be issued by Civil Defence National Headquarters for all ongoing investments. This may require hazard, vulnerability and geological risk studies which are carried out by entities whose corporate purpose is appropriate and which have been approved by the General Staff, a factor also promoting multidisciplinary involvement.

Several regulations and procedures are involved in physical planning issues which may be involved in risk management: land use plans, micro-location studies and macro- and micro-location certificates, as well as plans and strategies designed to meet national or local disasters. It thus follows that environmental protection, disaster prevention and pertinent requirements must be taken into account regarding any construction project undertaken in Cuba. Environmental management (*ipso facto* geological risk management) thereby involves various sectors of Cuban society in a multidisciplinary manner, without the need for excessive legal provisions being involved, leading to unnecessary legal red tape (Galban *et al.*, 2010).

The experience of recent years in Cuba has indicated that more specialists from fields unrelated to construction and hydraulics express their opinions every day on issues related to environmental risk management, and even propose measures to address certain situations, without even having technical knowledge regarding construction. As stated above, such situation

needs to be addressed and harmonically inserted in the construction investment process. Nevertheless, some examples highlight multidisciplinary intervention in geological risk management in construction and infrastructure in Cuba.

Results: analysis of the Mendive school project

A good example of construction projects in recent years which have been executed following the principles of geological risk management involving multidisciplinary participation in Cuba would be the *Rafael María de Mendive* senior high school restoration and rehabilitation project in the city of Santiago in Cuba. This city is located in a known seismic area situated at the contact borders of the North American and Caribbean plates (Figure 3) which has been affected by more than 1,000 earthquakes since 1528; 20 of them had an intensity equal to or greater than 7, 13 rated 7, 5 rated 8 and 2 rated 9 on the MSK scale (Table 1), making this area the one having the highest seismic risk in Cuba.

The Mendive project involved action aimed at promoting the structure's resistance against the impact of geological phenomenon. This project drew on the multidisciplinary involvement of institutions, professors, government and researchers from the Santiago de Cuba area, including the National Seismic Research Institute, the Universidad de Oriente (UO) Construction Faculty's Civil Engineering Team, the city of Santiago de Cuba's Conservation Project Office, Ministry of Construction Provincial Group's Enterprise Project 15 and the National Engineering and Architecture company (Beltran, 2010).

University professors played a decisive role in this work and influenced the implementation of new approaches to management, together with specialists from Project Company 15 (EMPROY 15) which was awarded quality management ISO 9001 / 2001 in 2005.

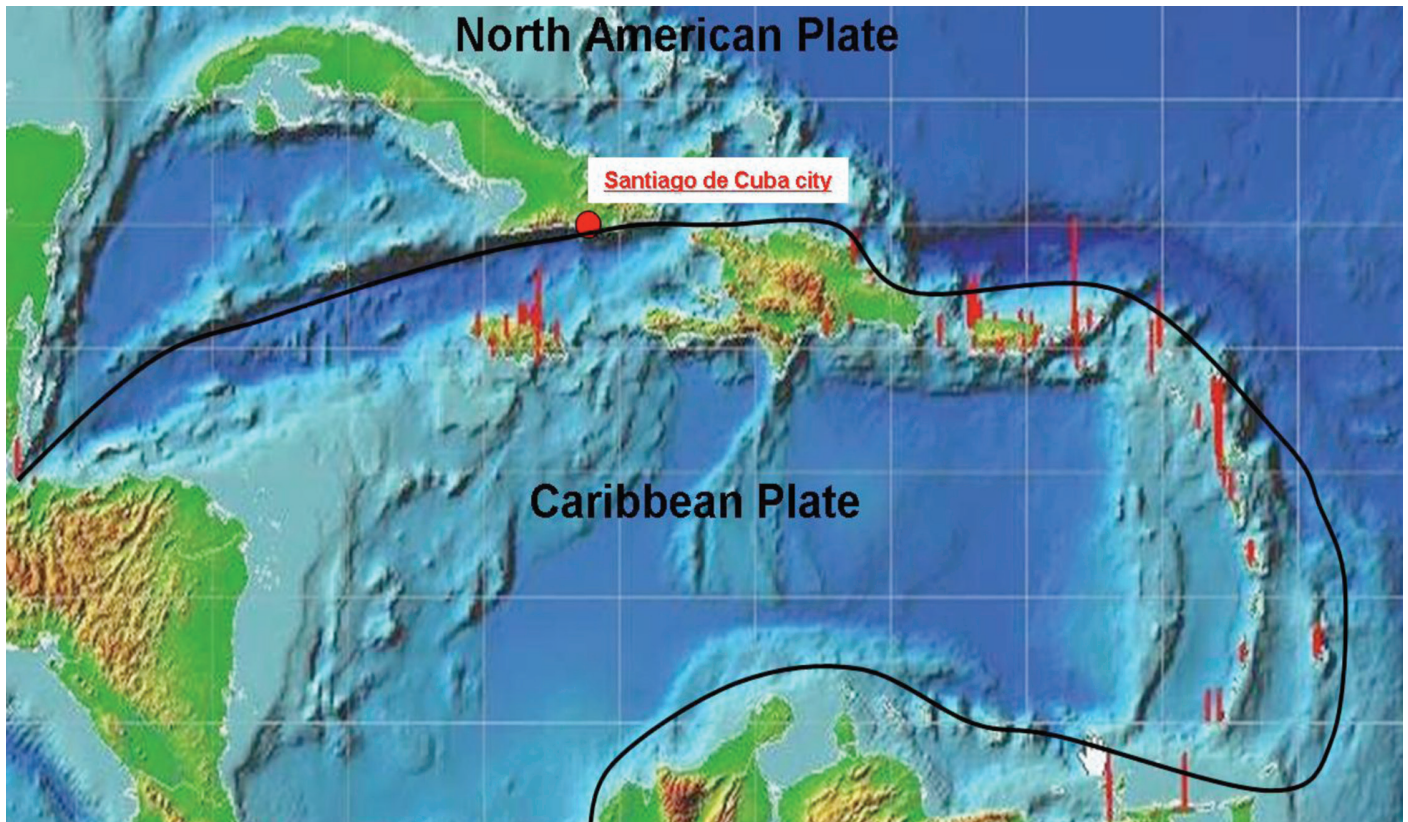


Figure 3. Location of the city of Santiago de Cuba within the boundaries of the southern part of the North American plate. (8° N. Lat., 57° W. Lon.) – (90° N. Lat., 24° W. Lon.)

Table 1. Strong earthquakes reported in Santiago de Cuba (Chuy Rodriguez, 1999).

Year	Month	Day	Hour	N. Lat.	W. Lon.	Ms	H	I (max)
1578	Aug		-	(19.90)	(76.00)	(6.8)	(30)	8.0
1580			-	(19.90)	(76.00)	(5.8)	(30)	7.0
1675	Feb	11	-	(19.90)	(76.00)	(5.8)	(30)	7.0
1678	Feb	11	14:59	(19.90)	(76.00)	(6.8)	(30)	8.0
1682			-	(19.90)	(76.00)	(5.8)	(30)	7.0
1752	Oct		-	(19.90)	(76.00)	(5.8)	(30)	7.0
1760	Jul	11	-	(19.90)	(76.00)	(6.8)	(30)	8.0
1766	Jun	12	05:14	(19.80)	(76.10)	(7.6)	(35)	9.0
1775	Feb	11	-	(19.90)	(76.00)	(5.8)	(30)	7.0
1826	Sep	18	09:29	(19.90)	(76.00)	(5.8)	(30)	7.0
1842	Jul	07	-	(19.90)	(76.00)	(6.0)	(30)	7.0
1852	Aug	20	14:05	(19.77)	(75.35)	(7.3)	(30)	9.0
1852	Nov	26	08:44	(19.50)	(76.25)	(7.0)	(35)	8.0
1858	Jan	28	22:04	(19.90)	(76.00)	(6.5)	(30)	7.0
1903	Sep	22	08:09	(19.90)	(76.00)	(5.7)	(30)	7.0
1906	Jun	22	07:09	(19.65)	(76.25)	(6.2)	(30)	7.0
1914	Dec	25	05:19	(19.45)	(76.30)	(6.7)	(30)	7.0
1930	Jan	17	12:00	(19.90)	(76.00)	(5.8)	(25)	7.0
1932	Feb	03	06:15	19.80	75.80	6.75	-	8.0
1947	Aug	07	00:40	19.90	75.30	6.75	50	7.0

Note: The values in brackets are macroseismic estimations of the parameters. Hour (UT), H (Km), I (MSK).

A report was prepared containing a seismic hazard, vulnerability and seismic risk study as earthquakes were identified as being the main geological hazard for the building. The report identified high vulnerability for the school as inadequate links with the structural system were observed, being subject to collapse following vigorous shaking. No security measures had been taken in the building and equipment and furniture were not adequate (Group of authors, 2007).

This report also contained results from tests made by the National Applied Research Company regarding soils and gave conclusions and measures for increasing the building's security:

- Calculations were made regarding structural vulnerability to seismic events using different methods, several of which are not included in the Cuban earthquake-resistance code;
- A strict control plan was designed and implemented based on the above measures. Greater security for work was thus achieved, successfully meeting a set of measures, regulations, standards and building codes contributing towards proper geological risk management;
- Indicators were observed when executing the project due to changes in the original rehabilitation design influencing a reduction in the building's vulnerability, for example, the behaviour of projected charges in soils was observed by adding concrete and steel structural reinforcement, finding that there was no significant settlement (Figure 4);
- Designing and injecting special concrete foundations and walls for the building (aerated concrete), especially made by the National Company for Engineering and Architecture of Havana

and The Concrete Company from the same province, thereby achieving greater compaction and increased resistance to the impact of severe seismic events (Figure 4); and

- A final report was delivered to the customer (investor) involving adjustments to be made to the building to increase its seismic resistance, also containing information about the conduct of future work so that the measures being taken would be respected.

The multidisciplinary group of companies, institutions and specialists who participated in the project were given a prestigious award in 2009 following analysis of the final results and after the National Conservation Award's Evaluation Commission had undertaken a detailed assessment of it. A press note read (Beltran, 2010) (Figure 5):

"[...] Quality Award was given to restoration companies working on the Rafael María de Mendive school in Santiago de Cuba, on the occasion of Cuban Architects' Day, in recognition of university student leader José A. Echeverría, who was killed during an assault on the Presidential Palace and the taking of Radio Reloj. Pedro Polo Castillo, director of the Engineering Services Company, received the certificate on behalf of all institutions and agencies involved in the restoration from 2001 to 2007. Norma Diaz Ramirez, an architect from the Ministry of Construction's Development Department presented the trophy and diploma.

Others worthy of honour were the National Centre for Earthquake Research, the Faculty of Construction's Civil Engineering Team, the City Conservator's Project Office, Project Company 15 and the National Engineering and Architecture project company.

Other entities involved were: the Ministry of Construction's Laboratory (Santiago), the Construction Business Group, the Escambray Com-



Figure 4. Structural reinforcement to increase seismic resistance in the Mendive project. Pictures courtesy of Francisco Calderín Mestre, project member.

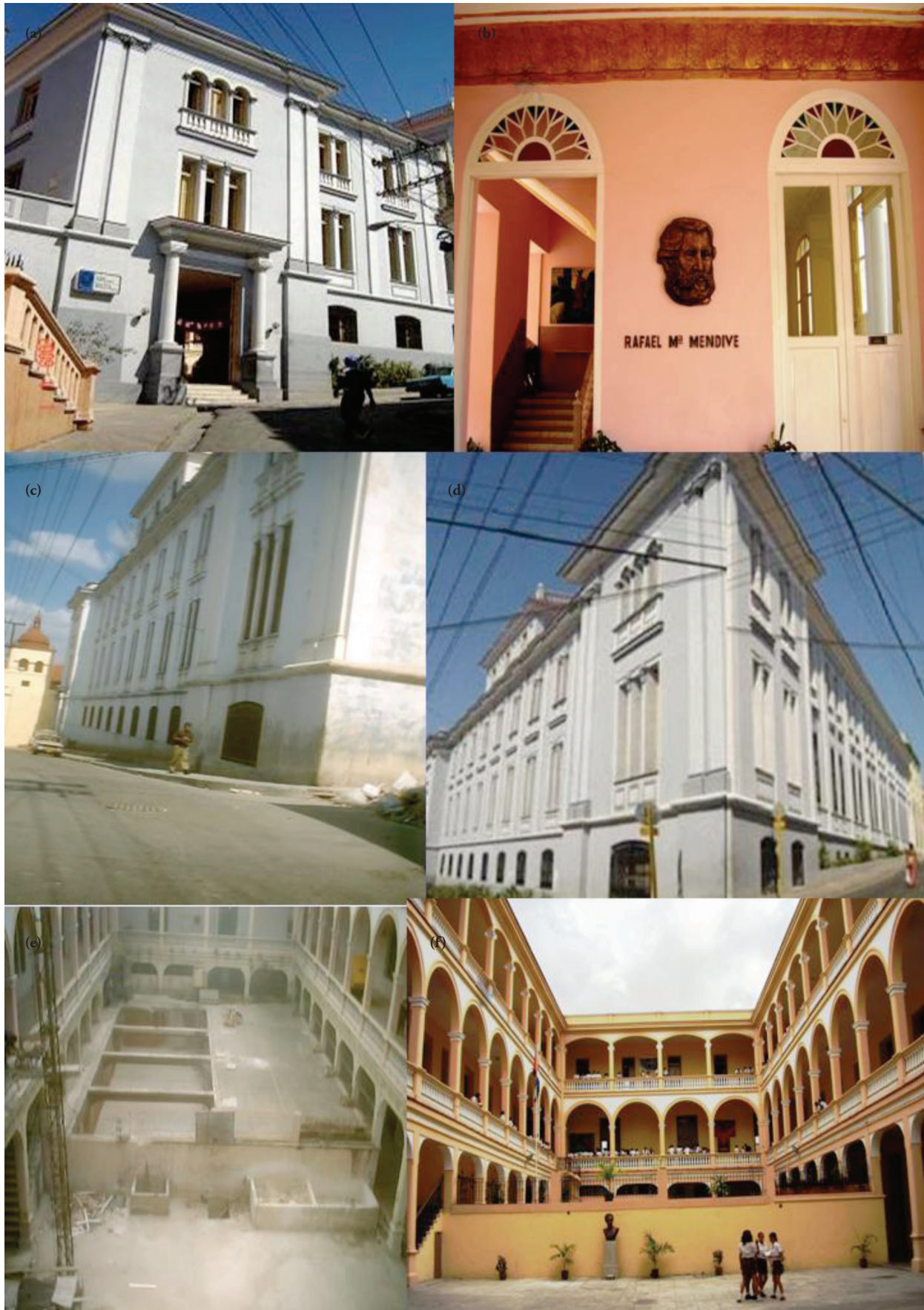


Figure 5. Photos taken before and after the work, courtesy of Francisco Calderín Mestre, project member.

pany, the endowment entity, the Santiago de Cuba and Las Tunas building materials industry, Marble Yard, Panorama Equipment, Engineering Works 11 constructions company, Vitral stained glass (country-wide paint seller), marine works, concrete company (Havana), COPEXTEL, architecture groups 2l, 56, 57 and 58, group 24 engineering, repair and maintenance/conservation group, and prefabricated equipment and service entities. [...]"

The National Bureau of Standards evaluated the project before awarding the Republic of Cuba's National Quality Award using renowned specialists' qualitative and quantitative methodologies based on a total quality management approach and practice (Beltran, 2010) whose principles are laid down in ISO 9001/2001, further defining management principles.

It is worth mentioning that this award directly validated the value of multidisciplinary involvement in geological risk management regarding construction investment from proven experience. It also reflected the need for gradually increasing collaboration between the different actors involved in geological risk management and construction work specialists sharing knowledge about risks.

Conclusions

One issue regarding international geological risk management for all levels of government involves multidisciplinary amongst specialists, government and the community, aimed at reducing the effect of geological risks (earthquakes, floods, landslides, erosion, sea action on coasts, etc) on man-made structures.

A literature review regarding such matters in Cuba confirmed that actions aimed at achieving multidisciplinary analysis concerning geological risk management had been taken, especially regarding intervention concerning Cuba's legal regulations.

The "Rafael María de Mendive" senior high school restoration and rehabilitation project in the city of Santiago de Cuba validated the value of multidisciplinary involvement in geological risk management regarding construction/investment.

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