The Protection Measurements of a Cultural Heritage Sites: Earthquake Disasters in Dana Village, Jordan

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Abstract
The impact of earthquakes on heritage sites is usually studied after a disaster has fallen and its impact on the site is evaluated. This study took the subject from a parallel point of view, which is the study of the state of the heritage site and its evaluation before a disaster. For this purpose, a heritage village in Jordan was chosen as a case study, the village of Dana in southern Jordan. Referring to previous studies and determining the research variables, the site was visited and the factors that could increase earthquake risks on site was studied.

The case was evaluated, preparedness strategies were reached and the most important procedures were identified in the preparedness plan stages. The study concludes that the construction methods and materials used were not the cause for weakness, but rather factors related mainly to usage, lack of maintenance and the extraneous materials to the current construction and therefore the proposed plan was to achieve one aspect of developing strategies to preserve the heritage site of Dana, which is the non-structural aspect (Qualitative Approach) that demonstrates the most important causes of damage. The structural aspect can be discussed and studied separately.

Keywords: Dana village, earthquake risk, architecture, heritage sites, protection measures.

Introduction

Despite the multiplicity of research to reduce the general vulnerability of heritage sites and the international declarations supporting the preservation of cultural heritage in various regions of the world, the access to practical measures on the ground to protect threatened sites around the world is enveloped by many political, economic and technical difficulties, especially if it is linked to sites of historical and heritage value declared on a national level rather than a global one.

Sites declared as national heritage are important because they represent the masterpieces of the creative human genius of our ancestors and they testify to their cultural traditions in addition to portraying the milestones in the history of the region and how our ancestors adapted to the surrounding environment by creating a civilization and an urban identity. These are the sites that need to be protected from the impacts of all risks due to their importance in cultural heritage and its development - a legacy from the past that must be preserved for future generations as they are indispensable sources of inspiration and reference points.

The international and national community must protect the integrity of such cultural heritage sites from the destructive effects of natural hazards and human-influenced disasters. Unfortunately, some sites with recognized cultural values have deteriorated because of such diverse calamities as earthquakes, volcanic eruptions, floods, land subsidence, pollution and acid rain and other natural disaster elements.

In 1994, a UN World Conference on Disaster Risk Reduction was convened to bring together Government officials, non-governmental experts and other specialists, all to discuss preparation, response and mitigation measures to face the growing incidents of natural disasters. Since then, two other conferences have been held: one in Kobe, Japan (January 2005), which adopted the Hyogo Framework for Action 2005 – 2015 and one in Sendai, Japan (March 2015), which adopted the Sendai Framework for Action 2015 - 2030.

The Strategy for Risk Reduction at World Heritage Properties was presented and approved by the World Heritage Committee at its 31st session in 2007. Its priority actions, listed below, were structured around the five main objectives defined by the Hyogo Framework for Action, the main UN-wide policy about Disaster Reduction existing at the time of its conception (2005-2015).[13]

1. Strengthen support within relevant global, regional, national and local institutions for reducing risks at World Heritage properties.
2. Use knowledge, innovation and education to build a culture of disaster prevention at World Heritage properties.
3. Identify, assess and monitor disaster risks at World Heritage properties.
4. Reduce underlying risk factors at World Heritage properties.
5. Strengthen disaster preparedness at World Heritage properties for effective response at all levels.

The case chosen for this study is the influence of potential earthquakes on the Dana Historical site, Jordan. Site's vulnerability was showcased in the sudden deterioration of 40% of the site's front and there was lack of a preparedness plan in addition to being close to a damping hole.

Research Method

Today Dana village is listed in the national register of heritage and natural sites. It reflects an extremely important period that documents the cultural, economic, political and social state at that time and exhibits its rural architectural style. Thus, Dana and many other Jordanian villages are very important and must be preserved. The lack of protection and safety criteria set for Dana village led to its deterioration and that can be viewed vividly in the unclear master plan outline. These problems increase the effects of earthquake risks on the site. Previous restoration works included two stages; the first stage was in 1995 and the second stage started at the beginning of 2009 and it is still in the proposal phase as tourism attraction functions.

Qualitative method is used to answer research problems with the collection, processing and analysis of qualitative data. Data collection techniques are mainly based on site visit, interviews with stakeholders and documentation. The data analysis used was descriptive analysis focused on important risk factors must be considered besides the efforts in the village. Those involved in the project should be aware of the earthquake risk that threatens the historic site and the urgency of the need to determine necessary earthquake prevention strategies.

This study aims to draw the attention of the local authority, the local community and researchers to the urgency of the earthquake risk hazard in Dana village by understanding the factors that could cause damage if an earthquake strikes the site and identifying primary strategies and guidelines for preventing and decreasing the effects of earthquakes in Dana as a preliminary plan towards more advanced and specialized studies and the structural strengthening suggestions that need to be set.

Results and Discussion

Dana village is one of many important dwelling Jordanian villages which was very lucky to be maintained without any unplanned growth like other villages, so it is considered as one of a few villages that reflects the pure image of Jordanian heritage sites constructed 120 years ago, in the ottoman empire period, all created from stone, mud and tree branches called Qusseib in the local tongue.

Throughout its history, the geographic characteristics of Dana Village have been significant. Dana is 1275m above sea level. It is located 30 km south of Tafila city and 230 km south of Amman (the capital). It is east of a damping hole near a green buffer zone and has a semi-arid Mediterranean climate. Winter has more humidity than its tendency to be dry. The average annual temperature is 14.1 °C | 57.4 °F. The annual rainfall is 320 mm | 12.6 inches. Dana's location represents the eastern part of the collapse crater (Afro-Asiatic), which extends from Africa to central Turkey, thus representing the faulted edge of the eastern Jordanian plateau overlooking Wadi Araba. Jordan's seismic map shows that the Dana region is located in a 2A zone, which means the potential seismic degree can be rich 5 degrees and that could cause severe damage. National natural recourses authority reports indicate that the Dana site faces many sequences of seismic activities in consecutive periods at a magnitude rate of 3 degrees.

Earthquakes can result in devastating destruction. While there is a growing body of knowledge about the nature of earthquakes, we cannot predict with confidence either their precise time of arrival or their intensity. Even with our present level of technology, we can do nothing to reduce either the frequency or the intensity of earthquakes[4].

Therefore, we must take action and be prepared. Some of these actions could include:

- Understanding the nature and causes of damage
- Learning from traditional construction in Seismic Areas
- Improvement of the seismic resistance of historic buildings
- Formulation of steps to organize disaster preparedness
- Guidelines for emergency safety measures.[14]

Understanding the traditional construction in seismic areas can tell us how people in the past have dealt with overwhelming earthquake forces on structures with technology and materials that were considerably more limited than nowadays. But experiences show that apparently vulnerable, traditional vernacular houses show a ductile behavior and absorb the shocks far better and the failures of vernacular houses are caused not by design failure[14].

During an earthquake in similar heritage sites, many of the houses, having crude and weak vernacular buildings survived nearly untouched next to collapsed apartment buildings. Inspection of destroyed traditional houses revealed another pattern. In many cases, the damage originated at exhausted areas such as rotted timbers and brick infill significantly degrading its performance during an earthquake.

Regular maintenance would have contributed much to the safety of these buildings. Moreover, many of the houses are altered and modernized in ways that interfere or rather corrupt the integrity of their original construction. If this is avoided by enforcing guidelines and codes, the extent of damage will be much less.

There is an urgent need and wide demand for non-structural standards and recommendations focusing on a range of problems from data collection, damage assessment and evaluation, inventory and mapping of hazards and stock at risk of creating thematically oriented Geographic Information Systems, warning systems and similar management tools, to progress in combating natural disasters. These non-structural standards will further support the development of technical standards and structural solutions for the prevention and mitigation of damage from earthquake hazards.[3]

After reviewing the Jordanian earthquake code, it did not address at all or set any standards for heritage buildings or even archaeological sites in the event of earthquakes, so accordingly, this study may contribute to directing consideration to the development of this item in the earthquake code and making it a reference for workers and researchers in this field.

Disaster prevention and reduction are actions that are interrelated with one another and they cannot eliminate disasters, but at least there must be efforts to reduce and prevent them from happening. In disaster risk reduction efforts, disaster mitigation efforts can be carried out by reducing the level of vulnerability because this will be easier than reducing the danger.[5]

Understanding the nature and cause of damage

Lack of maintenance and use: Buildings of this type are generally not well maintained and present visible signs of deterioration on elements like plaster, lintels and timber. The deterioration in these elements affects the structure above ground so it absorbs the seismic forces rather than transferring them to the foundation. The best way to protect the village is to make aware the villagers to maintain their residences in these structures. Protecting this rural architecture will be provide when providing modern services to the local inhabitants by improving the socio-economic conditions.

Weathering particularly of stone and mud mortar construction resulting in weak seismic resistance: The masonry stonework of the walls and arches is exposed, showing the masterpiece of stone construction. It clarifies the language, the dialog of gravity and stone used to their ultimate limits. Washed by annual rainfall, the view of the arches shows the perfectly clean stone, the inner skin having been completely washed away since the roof fell years ago.

On the other hand, looking at the stone walls from the west gives a different impression from looking at them from the east. The difference in appearance is caused by the direction of rain that comes every winter to wash the village walls facing west while the walls facing east have been accumulating dust since the beginning of this century[7].

The wall of many houses is partially destroyed, exposing in its section a double wall that is 120cm in width[7]. It is very likely that another layer, a second wall, was generally added to strengthen the western wall against the rain. Since walls are made of stone, unhewn mud is used to fill in the spaces so that the stones can stack resting on the maximum area of their surface and the mud filling “glues” the stone into the wall and protects it from falling and in return the stone protects the mud filling from being washed away completely by the rain.

This mutual protection is disturbed when water enters the wall from the top. This happens after the ceiling collapses or when the maintenance of the roof edges is poor.

Fig. 1: Lack of use

Fig. 2: Collapsed Ceiling

Fig. 3: Peeling plaster

Fig. 4: Vegetative growth traps moisture breaking the walls cohesive bonds

Fig. 5: After the ceiling fell, the rain washed off the mud plaster then deterioration started.

Fig. 6: West and east elevations

When a great amount of water seeps into the core of the wall, it forces the mud to fade and deteriorate causing the plaster to peel. Often the wall gets expands when the outer layer of stone separates from the rest of the wall, it buckles and collapses especially when earthquake forces affect the structure.

Understanding the structural causes of damage: If stones are used as a building material, with mud mortar, there is little hope that such structures will resist the effects of an earthquake. Typical damage patterns to stone and mud structural systems as a result of earthquakes can be broadly characterized under the following reasons:

1- Damage due to lack of proper structural joints.
2- Damage due to bad workmanship during construction.
3- Damage due to deterioration over time especially with lack of use and maintenance.
4- Damage to heavy masonry building due to their brittle character, minimal tension (on the other hand it can carry compression forces successfully) and minimal shear strength capacity[18].

The last reason will discuss the difference in the meaning of these two words- strength and power- to clarify when one deals with the question of why traditional buildings have remained elevated while some engineers might anticipate their downfall.

The basic principle in weak structure and filling construction is that there are no strong and rigid elements to attract forces. Strength can be used to describe the vertical carrying capacity of conventional structures, but these structures do not have much lateral strength. Usually, they have enough lateral capacity. These buildings give rise to earthquake forces by allowing low-level progressive damage in the form of "action" for the varying assembly of brittle materials. Despite the brittleness of the masonry and mortar and the individual woods remaining flexible, the system behaves as if it was "ductile".[2] If this process works properly during an earthquake, it is a process that can last for a long time before the degradation progresses to a destructive level. Thus, the buildings overcame the earthquake simply by not fully engaging with it. In addition, the high damping level eliminates the risk of the building hitting the ground, which is a major factor in the cause of earthquake damage to buildings. This is the difference between strength and capacity[8]

The connection between walls and arches raises the resistance of thrust forces that keeps the structure stable, so simply these structures should be adapted to seismic behavior to some extent. However, modern materials and technologies also have a potentially important role to play as adding seismic connections between house units to separate those structures and then earthquake resistance. But the new materials must be compatible with the traditional techniques and the method of construction to reach the integrity of the structural behavior. In addition, the new elements must be aesthetically compatible with the traditional materials.

Weak mortar (lime or mud mortar with little or no Portland cement): In addition to the salts that may form on the surface of the stone as a result of the reaction between the base cement and acid rain, a weak slurry (clay) is necessary for this phenomenon to work. Weak wall mortar allows production to begin under much less load than strong cement mortar. The pre-compression stress provided by the bearing weight of the wall, combined with the weak and unbreakable behavior of the mortar, allows stresses to spread throughout the wall rather than focusing on the length of the diameter.

Instead of a single large tensile crack, with cracking failure at the corners, the smoothness of the mortar encourages small, wide cracks across the mortar joints of the entire plate. This allows the building to dissipate energy and thus performs in a ductile rather than brittle manner[14].

The property of the clay mortar forming plastic hinges caused the ability of disparate materials, each of relatively low strength, to work together as a single system to resist catastrophic damage from the crushing forces of earthquakes - which is what makes these buildings so important. This example demonstrates that the traditional restoration method must be changed to trace these structure capabilities to counteract earthquake forces through ductile behavior. Mortars for construction work on intersecting walls should be weaker than masonry units. These mortars are best if they are rich in lime but are low in cement. Cement in mortar results in a strong but brittle mortar. This only exacerbates the possibility of concentrated crushing, rather than the distributed fine crushing necessary to "work" the wall[8].

Fig. 7: Joints between units must be treated according to structural seismic design

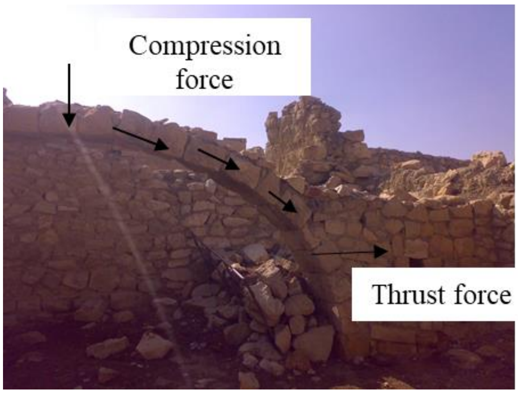

Fig. 8: Structural components

Fig. 9: Original mortar and restoration work mortar

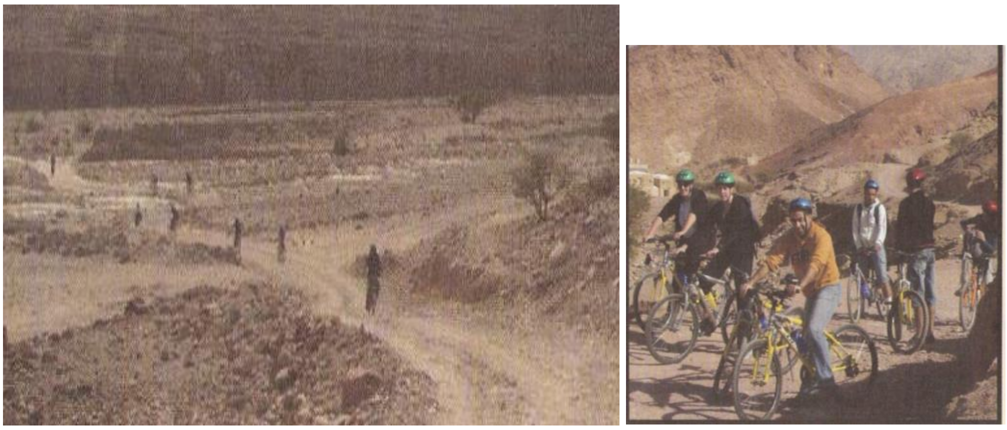

Fig. 10: Tourism impact on land vegetation that forms the defense line to the village

Impact of tourism: Dana guesthouse is present near Dana village. It usually receives visitors and the number of visitors is increasing every year. The effect of the visitors of the guesthouse is generally indirect. These visitors come to Dana village and some of them go on long walks to Rummana campsite or go down Wadi Dana and other sites on bike paths that caused Hiking trails. These trails should be controlled by limiting their width to have a minimal effect on the vegetation cover (defense line) that minimizes the potential soil drifting and floods effect. Any potential flooding as secondary hazard could affect the site especially since the site is famous for its abundance of water springs and wells, as indicated by the National Geographic Sources.

Infrastructure weakness: Dana village infrastructure is a threat to the site in case of an earthquake especially the topography running down from water supplies toward the village buildings. The drainage system and irrigation network are exposed and unplanned. At present, the village relies on old septic tanks and soil drainage for wastewater disposal as there is no central treatment facility. The potable water supply comes from a mixture of spring-fed sources, tankers and municipal piped supplies but there is no single, integrated supply network.

There are several actions carried out before natural disasters occur including preparing and repairing infrastructure to ensure the safety of the community from natural disasters, adequate design maintaining dikes and canals for smooth and fast flow of water, providing sufficient funding to renew all embankment systems which are the factors that contribute to disasters.[15]

Public awareness

Awareness concerning protecting cultural heritage from natural disasters consists of at least three elements:

1. Awareness of natural hazards and risks.
2. Awareness of the specific vulnerability of cultural heritage to natural hazards and of techniques for limiting the impact of natural disasters.
3. Awareness of possible measures and emergency procedures for mitigating the impact of natural disasters on cultural heritage. Of course, there are also other influences, e.g. understanding cultural heritage values, assessing rescue priorities, differences between the approaches and background of professionals and of the public etc.[3]

Unfortunately, Dana villagers leave the site because of the modernisation of the city. The remaining inhabitants are mainly old men and women or families with low incomes. People do not have the luxury to consider the cultural and historic value of the site they live in. Awareness-raising is firmly linked to educational and training programs. In addition, media-support and voluntary activities can advantageously use the national dimension to increase the impact, namely when young people and the internet are involved.[3]


Fig. 11: Unplanned and exposed drainage and irrigation system

Fig. 12: Water reserve

Fig. 13: Deteriorated pathways and use cars inside village paths in addition to extra roof loads.

Fig. 14: The falling water affects the base of houses and walls cover.

Fig. 15: The exposed wooden ceiling

Fig. 16: The settlement of base

Other hidden and temporal reasons: Some factors are hidden but serious in results, so must be taken care of in an earthquake preparedness plan.

1. Changing under earth water level makes the foundation unstable. There is evidence of excessive foundation movement (e.g. settlement) that would affect the integrity or performance of the structure in an earthquake.[4]
2. Frequent hidden earthquakes also affect the integrity or sum performance of the structure even the seismic force was not strong.
3. Wooden ceiling making the chance of fire spread available in earthquake case.

Earthquake preparedness strategies for Dana Village: An effective disaster mitigation strategy must include strict building supervision, transparency of design plans and accountability of public officials to reinforce safety considerations. The principles of disaster planning have been summarized by Taboroff:[16]

1. Disaster planning for a cultural heritage site should be conceived for the entire site including its buildings, structures and contents and landscapes.
2. The planning should integrate relevant heritage considerations within a site's overall disaster preparedness and mitigation strategy.
3. Preparedness requirements should be met in heritage sites by means that will have the least negative impact on heritage values.

1. Documentation of heritage sites, their significant attributes and history of disaster response are the basis for appropriate disaster planning.
2. Maintenance programs for historic sites should take into account a cultural heritage at risk perspective.
3. Property occupants and users should be directly involved in the development of emergency response plans.
4. During emergencies, securing heritage features should be a high priority.
5. Following a disaster, every effort should be made to ensure the retention and repair of structures or features that have suffered damage or loss.
6. Conservation principles should be integrated where appropriate in all phases of disaster planning and mitigation.[16]

Heritage structures and cultural property in seismic areas require specific actions, both administrative and technical. They can be broadly divided into: (a) before the earthquake (b) when disaster strikes and (c) after the disaster.[10] In the case of Dana village heritage site it could be as follows:

Before the Earthquake

- Documenting of all cultural resources. Currently, there is a real lack of any documentation.
- Training sessions to raise people's awareness of the risks, on how to react and behave before, during and after an event.
- The training and education of professionals and to focus on improving the quality of repair work after a disaster, as well as maintenance and other repairs that will enable cultural heritage to better withstand any exceptional loads in any potential earthquake disaster.[3]
- Standardizing a national code to determine techniques, skills and material needed for maintenance and restoration of traditional buildings to behave safely with seismic loads and any potential secondary risks, The National Earthquake Code lacks any specification regarding heritage sites or buildings.
- Prepare seismic safety plans for heritage sites to assess the sites and buildings to provide the specific data needed to develop cultural heritage protection plans in the municipality of Qadisiyah, to which the village of Dana administratively belongs and a specialized team should prepare and review such plans.
- Specialists should conduct case studies from traditional construction in similar seismic areas to improve the technical suggestions of the seismic resistance of traditional buildings.
- Prepare a safe infrastructure plan of water, electricity and firefighting systems, all of these systems should be compatible with the traditional values of the site.
- Improving the condition of the external roads leading to the site to facilitate the work of the conservation teams.

When Disaster strikes

- Suitably activating the fire fighting system.
- Controlling of secondary effects such as weather, looting and damage by water.
- Allow a multidisciplinary protection team to manage the site and request special assistance or equipment as needed.
- Forming emergency volunteer teams from the local community. Conservation teams must distribute tasks and coordinate.

After the Disaster- Long Term

- Professional documenting and assessment of the damage, culturally and structurally.
- Providing repairs and structural solutions integrated into the national standers and international guidelines.
- Estimating the costs of restoration to determine action plans and work phases.

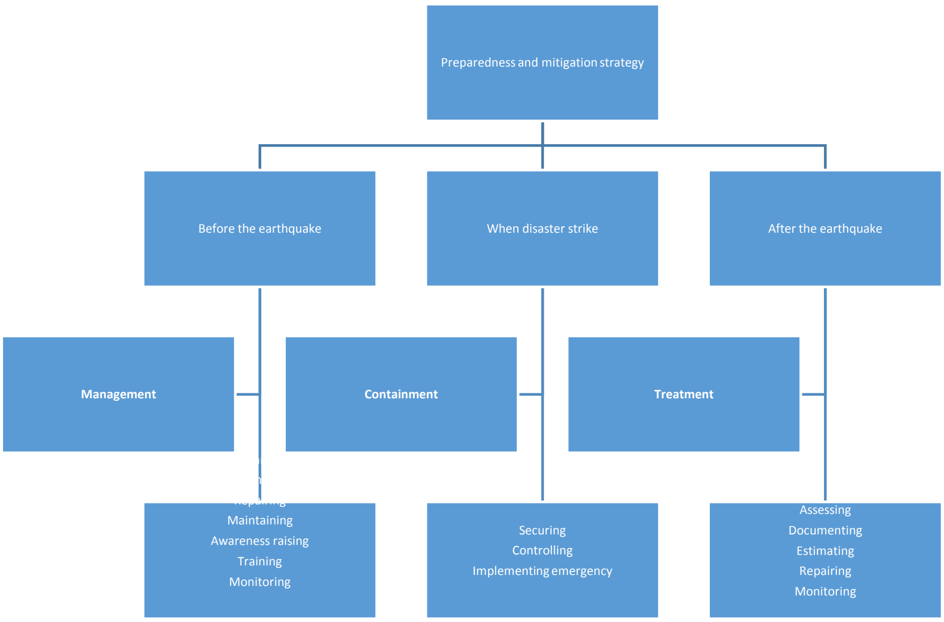

Fig. 17: Proposed preparedness strategy, author

Assessment Results: The site needs collaborative experts' team for public awareness, sustainable maintenance and protection comprehensive studies plan. The primary assessment shows that this type of construction will most certainly be destroyed during earthquakes with a magnitude of 7 or 8 degrees and severely damaged at intensities of 5 to 6 degrees[3] especially in the present poor condition and flail structure of the site; no longer serving its intended purpose and requiring major repair. This assessment must be inclusive of all specialist experts in this field to be more beneficial.

The priority is minor according to collecting data because there has been a lack of maintenance; deterioration may result in possible failure and deterioration will begin to affect related elements if not fixed in about five years. The maintenance or restoration works should apply the standards to minimize all the previous causes of damage spotted in the site, specifically the weathering and rain affect.

Conclusion

Earthquakes are different from other disasters in their capacity to destroy almost instantaneously without warning, causing extensive and often irreparable damages. We must take the responsibility of protecting the heritage sites in general because they are vulnerable and valuable.

Heritage sites in seismic areas show us the ability to adapt to earthquake forces on structures with traditional techniques and materials that were considerably more limited than nowadays. Due to the role of the soft mortar and the internal damping it provides, the system behaves as a ductile structure without any stiff elements to attract forces.

Despite this, the factors weakening the elements of the heritage buildings, which are discussed in this study for the village of Dana, may be sufficient reasons for these buildings to be affected by earthquake forces. These factors weaken the structure of the building as a whole and the links between its elements thus change its ductile behavior making it more fragile against earthquake forces.

Protection measures for the Dana cultural heritage site must develop a comprehensive plan and interdisciplinary methodology. All relevant parties must participate to identify and evaluate risks and causes that were discussed previously to the site from the earthquake and to determine practical and actual strategies before, after and during the risk and minimize their impact. Regarding the proposed strategy, the measures in the pre-earthquake stage are most important and require more actions to avoid consequences and facilitate work in the two subsequent stages.

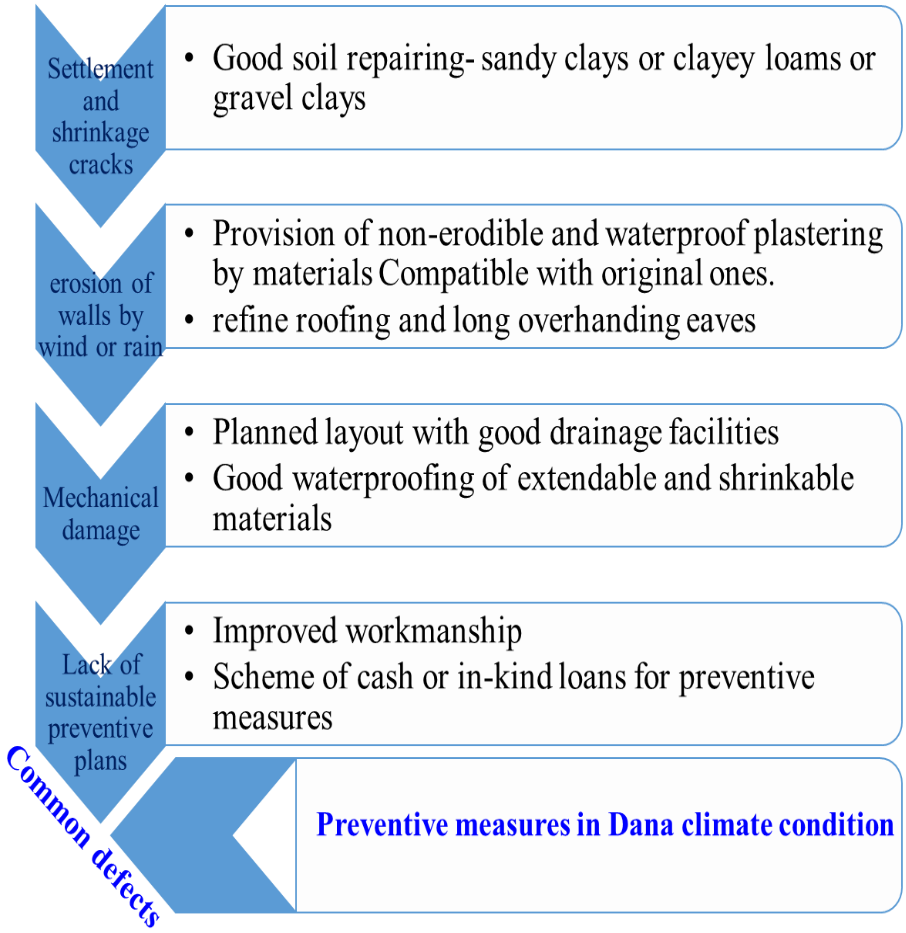

Fig. 18: Preventive measures layout elevations

The heritage and past experience in this site must be sustained and preserved. So, any restoration of the site must take into account the original behavior of the buildings and make in-depth studies for any structural treatments to be based on the values of the heritage sites and provide the most effective defense against earthquakes.

The environment surrounding heritage properties also should be considered in the disaster prevention measures like improving the condition of the roads, decreasing tourism impact, improving the irrigation and drainage system in the comprehensive plan, applying firefighting codes in restoration studies and preparing precise studies about geotechnical means to refer to the site data such as the effect of underground water and frequently hidden earthquake. This study tried to achieve one aspect of developing strategies to preserve the heritage site of Dana, which is the non-structural aspect. The structural aspect should be researched further.

Some recommendations to improve the site situation are: long term plan to improve the socio-economic levels to encourage the original inhabitants to live in the site and to reduce the loads and effects that deteriorate the site, to apply legislation to support sustainable maintenance and motivate the villagers to occupy their houses by improving community development and integrating volunteer tourism programs.

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