Rehabilitating Hazardous Structures in Rabat's Medina

Project Center: Rabat Morocco

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Date: October 16, 2015

Abstract

Rabat's mellah contains many hazardous structures which threaten the safety of its inhabitants. The cultural value of the mellah and low income nature of its residents pose unique challenges and opportunities to restoration of the area. This project used two mellah homes as a case study in order to explore the structural and social dimensions of home rehabilitation in historic areas. By benchmarking with other restoration efforts, a report was delivered containing recommendations towards a sustainable method for citywide rehabilitation.

Acknowledgements

The Hazardous Structures IQP team would like to thank our Sponsor Mr. Hammadi for his enthusiasm and direction.

Thanks to our advisors, Professors Stephen McCauley and Aaron Sakulich.

Thanks as well to Anas Eddik and Mustapha Channouf for their help with translation.

(Thank you very much) to the staff at Espace Hassan for dealing with our minimal French and Arabic in conjunction with our unending project discussions.

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Executive Summary

The medina of Rabat is a city ingrained with a rich cultural heritage. As the city has grown and changed, the stress of age has taken its toll on many of the medina's buildings. Many homes in the medina are in danger of full or partial collapse, particularly in the traditionally Jewish quarter called the mellah. Since a mass emigration of Jewish community to Israel in 1967, the mellah has become a home for the city's poorest residents. We worked with the Prefecture of Rabat to begin an initiative to rehabilitate the mellah and the medina as a whole. The goal of this project is to evaluate two houses and to understand the challenges that must be overcome to rehabilitate them, to research and suggest possible rehabilitation techniques for these homes, and to develop a process for future rehabilitation projects throughout the city. To accomplish this goal, the team completed the following objectives:

1. **Take stock of local information and organization assets**

We met with local resources including the Prefecture of Rabat, the US Peace Corps, and local residents. Each of these groups have different functions, resources, abilities, and specialized knowledge. By meeting with each organization, the team gained a more holistic understanding of the damage in the medina, as well as what rehabilitation options are feasible.

2. **Understand the challenges and opportunities of rehabilitating the medina on a large scale**

In order to understand the many challenges and opportunities facing the medina the team researched successful and ongoing rehabilitation projects. We toured numerous houses in the mellah to gain a broader picture of the current state of the houses. Additionally we met with ADER-Fes, the Agency for Densification and

Rehabilitation of the Fes medina, to learn about their organization and process for renovating homes and public buildings.

3. **Conduct a case study of 2 homes considering both social and structural aspects**

Site visits to the mellah provided opportunities to interact with the residents who were directly affected by this project. These visits provided context for structural damage in the mellah. This context was later used to identify major issues and areas that could use rehabilitation and to focus our research towards finding solutions best suited for mellah homes.

4. **Explore options for specific materials and techniques for rehabilitation and explore the advantages and disadvantages for their application in the mellah**

The team researched local construction and repair techniques for walls and roofs in order to address the various levels of structural damage seen during site visits. Roofing methods used outside of morocco were also researched in order to create a larger pool of potential solutions.

Findings

Through completing the above methods, the team compiled the following findings:

Local Assets

The local government has a vested interest in the rehabilitation of mellah homes, but lacks funding. In recent history, the prefecture contracted an evaluation of the entire medina on a structural level. This information along with other information gathered by the prefecture makes them a valuable asset in terms of rehabilitation.

Through meeting with the Peace Corps, our group learned that the residents living in the mellah are another key asset for rehabilitation. The Peace Corps

representatives we interviewed informed us that the unification of residents over a common goal, safety especially, can result in higher quality and longer lasting renovations.

Rehabilitation Strategies

ADER-Fes gave us a thorough explanation of their rehabilitation process during our visit with them. The process goes as follows; first, representatives conduct site visits to record family social information and complete preliminary evaluations of damaged houses. Second, ADER-Fes pairs the family with contractors to conduct the housing rehabilitation. ADER-Fes provides funding and supervision throughout the duration of the project. In addition to working on private residences, ADER-Fes completes rehabilitation projects on public buildings in order to both provide spaces for business as well as encourage broader economic development.

Conduct a Case Study

One main social takeaway from our site visits was the income level of the residents. Most residents have few resources and cannot afford a costly rehabilitation process. We learned that residents frequently attempt additions and renovations on their own, but these projects typically result in more structural problems. This is apparent in pilot house #1 where renovations made less than three years ago are starting to show signs of water damage. This is not an uncommon issue in the mellah; nearly every house we visited suffer heavily from water damage. Traditional building methods often fail to be properly waterproofed and as a result, wooden structural supports weaken under the weight of the ceiling and rooms become unusable. In the second pilot house, a 16-year old renovation using traditional methods is causing original load-bearing walls to crack and crumble. The added weight on the foundation has also caused the house to sink. In the medina, neighboring houses are connected and share load-bearing walls. As seen in this example, when one house sinks, multiple

houses are affected. This results in additional wall damage to structures that are initially structurally sound.

Technical Options

Site visits gave our group significant context in terms of structural damage in the mellah. Many problems we witnessed were a result of residents mixing traditional and modern building methods. While both modern and traditional methods both have advantages, they must be carefully tailored together to ensure success.

Traditionally, roofs are constructed with multiple layers. The bottom layer is comprised of wooden support beams and planks. Above that is a layer of insulating earth finally covered with a layer of cement or plaster. In many cases, residents also use corrugated sheet as a cheap method for building roofs. This is only a temporary solution as it needs to be replaced every three years do to weather damage. Alternate roofing methods researched include rubberized waterproof paint, EPDM, and fiber cement roofing. These methods are used outside of Morocco for waterproofing and constructing roofs and could be a viable options for mellah residents.

In addition to traditional housing methods, traditional finishings are a large part of the cultural relevance of homes. Many houses include intricate tiling and plaster carvings to decorate floors, walls, and ceilings. Painted and carved wood is often incorporated to decorate doors, tables, and ceilings.

Recommendations

By collecting and utilizing the above findings, the team compiled suggestions for the prefecture to aid in the rehabilitation process. The recommendations address the different scopes of the project, the house specific technical renovation, the large scale rehabilitation of all the houses in the mellah, and finally recommendation for the broader urban development of the mellah.

Technical Recommendations

First, due to the case by case nature of damage, we recommend that a professional engineer evaluates each and every home being renovated before work is done. With that in mind, we recommend that modern methods of rehabilitation such as waterproof paints and fiber cement roofing are used due to their long term effectiveness. Finally, in order to conserve the cultural relevance of rehabilitated homes, we recommend that traditional aesthetic finishings are used to decorate any modern structural supports.

Organizational Recommendations

In order to implement the aforementioned technical recommendations, we recommend the Prefecture of Rabat establish an agency that can coordinate and oversee rehabilitation projects in the mellah. This agency's responsibilities should be to pursue funding, conduct initial housing evaluations, and coordinate residents, contractors and artisans during the rehabilitation project.

Large Scale Recommendations

In addition to working with individual residences, we recommend that this newly implemented agency operate on a larger scale and maintain and rehabilitate public buildings and landmarks. Many collapsed buildings in the mellah have great potential to become sources of revenue for the government and the citizens. We recommend this new agency reclaim abandoned property and rebuild the empty lots into spaces for new businesses, shops, and artisans.

1. Introduction

As the world modernizes and the pace of life quickens, historic buildings across the world are undergoing substantial degradation, and many nations are just now beginning to establish measures to preserve these sites. Morocco has recently joined this worldwide campaign with the goal of protecting the plethora of historical sites within its borders.

Morocco maintains a unique cultural heritage through its many historical sites. Some of Morocco's most valuable historic sites are the functioning medieval cities known as medinas. Medinas are comprised of densely packed residences and markets along with historic structures such as religious monuments and ancient fortifications. The medinas of Morocco are considered to be some of the best conserved historic cities of the Arab world and they retain the majority of their original functions. The medinas of Marrakesh, Essaouira, Tetouan, Fes, and Rabat have all been recognized as official UNESCO cultural world heritage sites. UNESCO describes the medina of Fes saying "it not only represents an outstanding architectural, archaeological and urban heritage, but also transmits a life style, skills and a culture that persist and are renewed despite the diverse effects of the evolving modern societies" (Medina of Fez, 2015). Morocco's timeless medinas are invaluable historic assets that need particular attention to ensure they are preserved.

The Moroccan government was spurred into action in 2010 following the collapse of the minaret of the Bab Berdieyinne mosque in Meknes (Criticism mounts in Morocco, 2010). This tragedy renewed the focus on Morocco's need to repair infrastructure.

Despite its tragic implications, this catastrophe has had a positive impact on the nation's rehabilitative legislation.

As the capital, Rabat serves as a hub of government and modernization for Morocco. Rabat features a number of vibrant historic areas which contrast with the newer parts of the city, specifically Rabat's medina, which has signs of relative neglect compared the burgeoning modern areas. Of these medina structures, only 32% are considered to be in good shape, with the rest standing in various states of degradation (Technical Data, 2012). Many tenants residing in the medina face poverty and are unable to afford rent increases. This is problematic because landlords are currently not making enough money from tenants to be able to afford necessary renovations.

Rabat has acknowledged the relevance of preservation of its medina since the early 20th century, with different departments and organizations working to keep buildings standing and public works functioning (Théliol, 2014). The Prefecture of Rabat, the local city government and sponsor of this project, has recently begun a more modern renovation process by employing a number of architectural firms to evaluate the state of the medina. While some progress has been made to improve the quality of buildings in Rabat's medina, there is still an amalgam of issues yet to be considered.

This project aims to support the prefecture's efforts to preserve the deteriorating medina. We focus specifically on the mellah, a neighborhood on the edge of Rabat's medina that is in particular need of rehabilitation. The mellah is the historically Jewish quarter of the medina and had been a strictly Jewish section of residence until the 1960s when major emigration left most of the homes available to new residents. A vast majority of houses in Rabat's mellah were abandoned and filled by immigrants from the

countryside moving into the developing urban area. Over the last 50 years, historical degradation was accelerated due to high population density, increased building stress from structural additions, and the residents' lack of resources to repair their homes. As collapses become more frequent, the rehabilitation of the mellah has become a pressing and intricate issue.

This project investigated effective methods for rehabilitating buildings in Rabat's mellah. This project devised an effective method for the social and structural evaluation of damaged homes in Rabat's medina. A more holistic understanding of social and structural issues was developed via a piloted case study with extensive on-site data collection of two selected residences in the mellah. This case study was then used to make recommendations for the effective rehabilitation of the chosen residences, as well as to make broader suggestions towards a city-wide approach to rehabilitation.

2. Background

2.1 Significance of Rabat's Medina

As both the modern capital of Morocco and an historic city, Rabat performs a careful balancing act of old history and new development. Rabat was founded in the 3rd century BCE as the city Chellah, later being captured by the Romans in 40 CE and renamed Sala Colonia. In 1170, the city was renamed Ribat Al Fath after being shown to be an impressive stronghold (Technical Data, 2012). The medina (see figure 1) is one of the oldest sections of the city, founded in the early 12th century. It is occupied mostly by markets, restaurants, and other local commercial businesses (Bindschedler, 2013). It is a center of tourism in Rabat and its presence has contributed to Rabat becoming a United Nations Educational, Scientific and Cultural Organization (Rabat, Modern Capital, 2015) recognized world heritage site.

Figure 1: Satellite view of Rabat (Rabat Google Map) with the medina borders highlighted with the mellah highlighted in red

2.2 Architecture of Rabat's Medina

Figure 2 : Exposed Brick wall with plaster being replaced

The medina is the oldest section of Rabat, and is tightly packed with residential housing. The majority of the residences follow a traditional layout including a central courtyard typically surrounded by bedrooms, bathrooms, and a kitchen. The most common style of architecture in Rabat's medina consists of two or three story buildings comprised of stone or brick with a lime mortar (figure 2), which is then covered in plaster. Wooden columns and beams are used for support and roofs are made of wood, layered reeds, and clay mortar (Omira, 2010).

Other homes in the medina are not professionally engineered and are constructed by residents with a variety of local materials. These poorly constructed buildings are generally single story homes comprised of brick or stone; the walls of which are usually made of earthen mortar or timber, both with little or no reinforcement in the form of columns or beams. Buildings made of timber are often improperly anchored to typically shallow foundations (Omira, 2010).

2.3 History of the Mellah

Many cities in Morocco have a Jewish quarter labeled the mellah. Rabat's mellah is located in the corner of the medina, off of the two main streets Rue Souika and Avenue Mohammed the V. While the quarter was historically inhabited by Jewish

residents, the homes have since been vacated and subsequently occupied by other Moroccan citizens. This emigration was part of a larger movement of Jewish residents that included more than 250,000 Jews who left Morocco before 1967, with a majority departing as early as 1951 (The Virtual Jewish World, 2008). During an interview at a synagogue in Rabat, a local Rabbi reported that Jewish people who originally lived in the Mellah abandoned their houses to live in Israel. After this emigration new residents, mainly rural migrants, claimed the abandoned buildings. These new residents lacked the resources required to maintain their houses, leading to an increase of building damages since their arrival.

Recently, a series of consultants reviewed cases of hazardous structures in the mellah and surrounding areas. These consultants provided the prefecture with data involving the damage to individual residences as well as information on the medina as a whole. Accompanying this data, the prefecture has a variety of maps charting ruined and damaged buildings throughout the medina. Figure 3 shows a section of a prefecture map of the medina. This specific section of the map shows the mellah, which has a high density of ruined or in danger buildings.

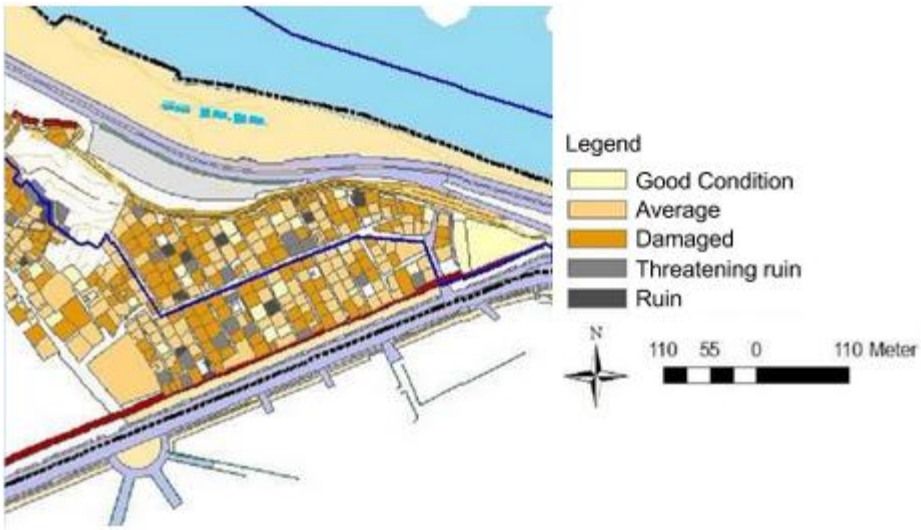

Figure 3: Map of building conditions in Rabat's Mellah

There are many causes of this high density of ruin, most of which are exacerbated by high population density as experienced in the mellah. Minakshi Mani (1998) details the issues of human interaction with these dilapidated structures in her master's thesis. She states, "Population growth and demand for housing has resulted in a subdivision of properties, thus causing an increase of burden on the infrastructure and similarly the degradation of immovable property" (Mani, 1998). At the time of this study, the average number of people per household in the medina was 6.19 (1.83 persons for room). As a result of high demand for housing, landlords became less responsible and less capable of repairing buildings to the level desired by their tenants. Minakshi goes on to say, "This pattern of occupancy over time has caused a slow decay and deterioration of these properties. The repairs that have been made are usually incompatible both structurally and visually. This structural incompatibility leads to further damage and cracks." Other factors like different thermal expansion coefficients of cement and lime plaster can intensify cracks and eventually detach plaster from walls.

Some efforts have been made in the past to improve living conditions in the mellah, but these efforts often result in structures becoming hazardous. One example of a poorly installed utility causing damage is the government-funded installation of water pipes to homes in the medina. As many as 56% of residents share a drinking-water source and 41% share a toilet. The addition of water connections to create independence between residents resulted in unexpected issues. Water lines were built both externally (figure 4) and underground, and while the pipes above ground are visually displeasing, the pipes below ground pose a larger structural issue. Pipes below ground leak, and this leaked water penetrates the subsoil, thus affecting the buildings' foundations (Mani, 1998).

Other information provided by the prefecture included data about many structures' health, occupancy, and ownership, as well as which structures bear historic importance. Much of the prefecture documentation highlights the depth of cultural heritage prevalent in the mellah and wider medina. Conservation of this area is a twofold need, to both protect residents and the historical buildings they occupy. Often these needs are at odds with each other, thus the challenge becomes achieving a balance between action necessary to ensure safety and preventing renovations that too drastically alter the cultural landscape of the area.

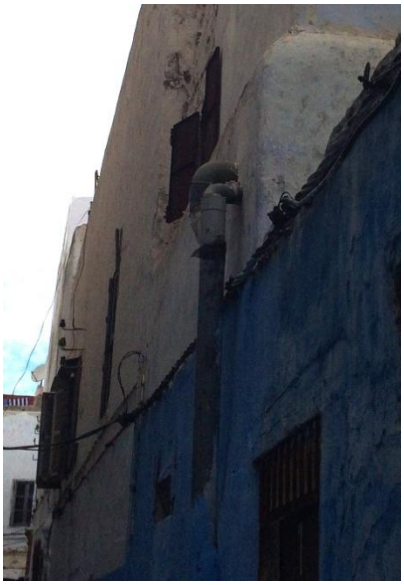

Figure 4: Exposed drainage pipe in mellah

2.4 Government Strategies for Medina Rehabilitation

Much of government strategy for rehabilitation revolves around first the obtainment of funds. One of the most effective ways to utilize historic regions to generate funds is through tourism. Since the signing of the Framework Agreement between Morocco's government and private sector, Morocco's government has named tourism a "national economic priority". In 2001 Rabat's new king, Mohammed VI, created the "Vision 2010" plan to improve Moroccan infrastructure and bolster tourism. This plan was a success, and in 2010 Morocco saw nine million tourists, three times as many that visited in 2000. Following the success of the “Vision 2010” plan, the Moroccan government has unveiled the "Vision 2020" plan which aims to double the number of tourists annually to 18 million by 2020 (Tourism, 2015). As a significant tourist attraction in Morocco, the medina of Rabat can be expected to be one of the focuses of the 2020 initiative. This expectation makes the development of tourist infrastructure a time sensitive investment for Rabat that if acted on could result in significant dividends.

While Morocco’s tourism industry is booming, this is not the case for all government sectors, and wealth made through tourism is not necessarily applied back to the region that generated the funds. Despite the renovation initiative in 2001 many buildings in Morocco have not received necessary care. This lack of proper care culminated in the previously mentioned mosque collapse in Meknes. An article from “The National” stated that local residents wanted to know why the Mosque’s structural integrity had not received proper attention. One local, Mr Charker asked, “What happened to the budget set aside for this work? Local authorities did not listen to the

people," another resident, Imad Nabali, said "What are our elected officials there for?"(Criticism mounts in Morocco, 2010.) Moving forward the Government is making a serious effort to rehabilitate buildings, but there are still many budgetary concerns.

2.5 Urban Rehabilitation Background

There are a number of motivations and challenges involved in the process of rehabilitation which are outlined in Florian Steinberg's paper *Conservation and Rehabilitation of Urban Heritage in Developing Countries* (1996). Steinberg explains that existing land and housing is an important resource for solving overcrowding that occurs in many cities, and can still play a key part in boosting the economy. The damaged state of low income housing is a result of a growing economy. Resources are spent on building new buildings, and as a result there is no focus on the upkeep of the old structures. Eventually the older buildings erode into a damaged, possibly hazardous state. Steinberg also explains that it is more beneficial to fix the crumbling buildings than to bulldoze the ancient cities to the ground. Fixing already established structures reduces the displacement of current residents, preserves the cultural and social heritage of the area, and can help generate revenue through tourism. The ultimate goal is to make historically relevant structures useful and sustainable.

There are many factors that need to be considered before, during, and after a large-scale rehabilitation project. These factors include political uncertainties, cultural questions, social challenges, economic challenges, etc. Consistent government progress is a large issue that needs to be considered. Rehabilitation can take a long time, and generating and maintaining political support can be a challenge. It is the government's responsibility to implement policies to be followed during the process of rehabilitation.

It is important that they contribute rather than hinder said process. Steinberg explains that an effort should be made to involve residents during the planning stage of the rehabilitation. Residents are directly affected by these projects and have the most to gain, but also the most to lose. The demographic of residents in these degraded regions is often comprised of poorer locals who are at risk of displacement and gentrification during and after the rehabilitation process. Additionally both residents and the government are faced with the big question of who pays for renovations. Residents often cannot afford renovations, and governments are often low on resources.

2.6 Fes Rehabilitation

The medina of Fes, the largest in Morocco, had undergone severe structural degradation but now serves as a model for successful rehabilitation efforts, and the application of urban development techniques. This 9th century city has a rich cultural and historical background and was recognized as a UNESCO World Heritage site in 1981. The Fes medina is a large tourist attraction and contains 150,000 residents, but the structural integrity of the ancient buildings put many lives in danger due to potential collapse. The organization known as ADER-Fes (Agence pour la Dedensification et la Rehabilitation de la medina de Fes) was created by the Moroccan government in 1989 to manage the preservation of the deteriorating medina (Powers, 2014).

The Fes medina has been subject to an amalgam of structurally damaging factors beyond general historical deterioration, with an increase of this degradation beginning in 1967. This increase in 1967 coincides with a shift in the economic structure of Morocco as well as a large exodus of the Moroccan Jewish population. During this time, the Moroccan government began modernizing cities which drew people away from the

medina and it's antiquated economy. Abandoned buildings fell into further disrepair. Remaining medina residents became absentee landlords to provide a source of income, renting out their homes to multiple poor rural migrant families. These migrants were unable to invest in the upkeep of their homes as their stay in the medina was brief and their resources were limited. This lack of upkeep and high population stress caused building damages that needed to be addressed. Landlords were responsible for repairs but often used the cheapest available materials and labor. These poor quality repairs inevitably lead to further building damages. Historical wear, abandonment, lack of upkeep, high population, inadequate resources, and deficient repairs contributed to a concrete need for action to rehabilitate the medina of Fes. (Powers, 2014)

ADER-Fes created a rehabilitation plan that started in 1995 by collecting information in an in-depth study of the medina. The Fes preservation movement was funded by international efforts including UNESCO and The World Bank. The World Bank recognized that the preservation of the medina's heritage had economic benefits not just from tourism but by reducing poverty and stimulating the local economy. Working with ADER-Fes, UNESCO, and the Moroccan government The World Bank loaned the Fes rehabilitation project with loans equivalent to $14 million. The project design that received this funding had three goals: to improve the medina's infrastructure, to preserve the medina's unique historical assets, and finally to improve the quality of life for medina residents. The World Bank's money not only went towards fixing broken buildings, but had a direct impact on over 50,000 residents in Fes who lived in poverty by creating jobs with onsite training for unskilled workers. (El-Ghazaly, 2008)

When dealing with residential rehabilitation ADER-Fes acts as a consultant instead of directly intervening and rehabilitating. ADER-Fes guides residents through the restoration process. First a homeowner will submit a series of application forms which are reviewed and then money is provided to the homeowners for rehabilitation services. The homeowners are then presented with a list of engineers, architects, and contractors to choose from to proceed with the realization of structural repairs. This process closely involves residents with the restoration so they will be more invested in the process to ensure effective contributions from a determined community. (Powers, 2014)

A key department within ADER-Fes is the recently added Social Team. This team focuses on social issues brought up during rehabilitation and serves as an intermediary between ADER-Fes and medina residents. Social issues include family income, displacement of residents during construction, and general distrust of government agencies which hinders communication and progress. ADER-Fes faces skepticism from residents so the Social Team assigns a single person responsible for each individual neighborhood. This person is a direct representative between ADER-Fes and the residents who communicates about specific cases to address social issues. This representative visits sites and becomes familiar with the area and the residents, creating a more comfortable environment of talking with one person instead of dealing with an entire government agency. Having this social team greatly facilitates communication and trust while effectively identifying dealing with social issues. (Powers, 2014)

3. Methodology

This project is a pilot assessment of degraded homes in Rabat's mellah. Through this assessment, this project makes recommendations towards the rehabilitation of specific homes, and expands its findings to the scope of broader urban development. To make accurate recommendations it was vital to focus on both social and structural challenges and opportunities present in the area. The following objectives were set to facilitate a thorough assessment and accurate recommendations.

- Take stock of local information and organization assets
- Understand the broad process and challenges of rehabilitating a historically significant area
- Conduct a case study of 2 homes considering both social and structural aspects
- Explore options for specific materials and techniques for rehabilitation and explore the advantages and disadvantages for their application in the mellah
- Provide recommendations for rehabilitating the pilot houses and suggest measures that may help renovation on a larger scale.

3.1 Take Stock of Local Assets

3.1.1 Information Assets

One challenge of working in a developing nation is the limited availability of information. Due to this, the process of gathering information shifted from online research to near exclusively conducting interviews and setting up meetings. Our first step was to gather information on the current and past state of the mellah. The first and largest contributor of information was Hammadi Houra, the Head of the Buildings

Department for the City of Rabat. By conducting brief informal interviews with Mr. Hammadi, we were able to learn common tools and methods that had been used previously by the prefecture and other organizations during rehabilitation efforts. We also explored documentation provided by Mr. Hammadi that covered historically significant components of the medina and mellah.

We additionally sought historical information from a local synagogue via an informal meeting with a rabbi. The information gathered from this interview provided useful background context for understanding the sequence of events that brought the mellah to its current state.

3.1.2 Peace Corps

Two members of the team visited the Peace Corps (PC) headquarters in Rabat to conduct an informal interview. This interview was focused around three research topics: current initiatives or plans for the mellah/medina by the PC or local organizations, additional studies or historical information regarding the mellah/medina, and effective methods for engaging local organizations and residents. These research topics were explored in depth with a larger set of questions that can be found in Appendix A.

3.2 Understanding the Broad Process of Medina Rehabilitation

3.2.1 Urban Development Research

A great deal of research and study has been done by experts in the field of Urban Development. To understand successes and failures of different urban development approaches we examined a series of case studies and examples of urban development in the field. During this research we focused on capturing methods which were most

applicable to Rabat and acknowledging failures which could likely affect mellah rehabilitation.

3.2.2 ADER-Fes

To expand our knowledge of urban development strategies, we pursued a meeting with ADER-Fes due to its proximity and relevance to the mellah's situation. Fouad Serrhini, the director of ADER-Fes, set up a tour of sites undergoing rehabilitation with an ADER-Fes employee, Zouheir Hassan. Our primary goals for this meeting was to learn more about the operation and formation of ADER-Fes, and their methods for assessing homes. On this tour we took pictures of finished rehabilitated structures and buildings in the process of construction. We also informally interviewed our guide, focusing on ADER's methods of funding, planning, and supervising projects. We also inquired about the set of companies and contractors that work with ADER and what guidelines and expectations were set for their employment. Lastly we explored major obstacles and challenges faced when working in an historically significant urban environments.

3.3 Conduct A Case Study

Site visits to the mellah provided opportunities to interact with the residents who were directly affected by this project. These visits provided context for the mellah, which was used to identify major issues and areas that could use rehabilitation and focus our research towards finding solutions best suited for mellah homes.

3.3.1 Preliminary Visits

As outside researchers, it was crucial for our team to become familiar with the setting of our project. In order to obtain a basic grasp of the area, we conducted two

preliminary visits prior to fully beginning our case study. Our first visit was an unguided walkthrough of the mellah. We chose to have our first walk through without a guide so that we could attain an outsider's perspective; we knew that later guided visits would provide a much closer perspective on residents and the culture of the area. We took limited notes and photographs during this visit in order to not draw attention to ourselves. Additional precautions included dressing conservatively.

Our second preliminary visit was a guided walk through of the mellah led by Mr. Jaouad, an architect who lived in the mellah. This site visit was dedicated to learning about resident perspectives on living in the mellah and residents' satisfaction with available housing. Our group also used this opportunity to introduce ourselves and our project to residents. During this walk through we continued our efforts of building trust with residents by continuing to dress conservatively, taking notes and photos only when invited, and avoiding asking questions in favor of listening to local anecdotes and perspectives. This visit had components that we did not initially expect, namely, the large volume of homes we were shown, the rate at which homes were assessed, and the impromptu addition of homes to the visit as residents noticed us and extended invitations. This visit served as a foundation for us to structure our next site visits by allowing us to assess which research questions we felt needed to be explored in depth.

3.3.2 Case Study Visit

Questions during our case study visits were divided into two categories: structurally oriented questions and socially oriented questions. Our structurally oriented questions focused on assessing the physical structure of the homes and exploring challenges that residents faced with repairs while our socially oriented

research questions were asked to help guide our recommendations for broader rehabilitation of the mellah. We avoided asking questions that could be perceived as sensitive topics. Sensitive questions, while possibly providing useful information, have the potential to damage trust and may result in falsified answers. Site visits were conducted in an informal interview format in order to make our research less distant and more focused on resident perspectives. Similar to our guided walk through, we focused primarily on the stories and perspectives readily offered by the residents.

Our structurally oriented questions focused on knowing the answers to four major topics: what types of damage are present, what are leading causes of damage, what measures have residents taken to address these issues, and how effective are those measures. By answering those questions, we were able to focus subsequent research on solutions and options that might be most useful for residents in the mellah. A complete list of structural questions can be seen in Appendix C.

We divided our social questions into three main topics:: what resources do residents have to invest in rehabilitation, to what extent do residents view rehabilitation as a priority, what major challenges to rehabilitation afflict residents. These questions allowed us to explore options for facilitation of rehabilitation for the mellah on a broader scale. A complete list of social questions can be seen in Appendix B.

3.4 Possible Reconstruction Materials and Techniques

As outside researchers our team had the prerogative to provide fresh outlook and options in regards to reconstruction materials and techniques. We focused on exploring materials and techniques that may be effective in the mellah granted its unique combination of structural and cultural aspects. We also used our site visits and meetings

with ADER-Fes and Mr. Hammadi to understand current methods of roofing construction. Finally we investigated the advantages and disadvantages of traditional methods.

4. Findings

4.1 Local Assets

During our initial meeting with Mr. Hammadi, we were informed that the government has very limited funding allocated for building rehabilitation. An emergency fund can be tapped into when a structure poses an immediate threat to residents, but all money taken from these funds need to be paid back over time. Due to this overwhelming lack of funds, the prefecture emphasized the need for residents to pay, at least partially, for renovations to their homes. A supplementary document provided to us by Mr. Hammadi states that due to this lack of funding, solutions that are proposed must be treated by the government as an investment and therefore need to include a method for economic sustainability which introduces an entirely new set of challenges addressed later.

In addition to a critical lack of funds, Mr. Hammadi informed us of the state of buildings in the mellah. We learned that infrastructure varies between many homes in the mellah; not all buildings have electricity, running water, proper plumbing, or proper structural supports. Additionally, many buildings in the mellah were constructed with a lime or gypsum mortar which has quickly degraded resulting in masonry falling apart. On top of these shoddily prepared supports, it is common to find roofs made of small wooden timbers supporting up to 45 cm of brick or concrete above. This excess weight on top of weak supporting materials creates a serious threat of collapse.

4.2 Rehabilitation Process and Challenges

After meeting with the Prefecture of Rabat and discussing available assets for rehabilitation projects, we met with two Peace Corps representatives: El Mostafa

Lamqaddam, the Country Program Support Manager, and Azeddine Habiballah, the Regional IT Specialist. They informed us that the Peace Corps in Morocco is currently focused solely on youth development and has not done any work with the rehabilitation of hazards structures. That being said, they offered us useful insight on common challenges found in medina settings and methods to circumnavigate these challenges.

Lamqaddam and Habiballah stated that when working with and planning a project to benefit a community, communication is key. All community stakeholders need to know each others goals in order to reach a successful end and furthermore, when different groups have different goals not all key issues will be addressed and cooperation will be hindered. The Peace Corps representatives stressed that people in communities need to be significantly involved in an outside organization's planning process because a plan made without deep consideration and involvement of said community will result in the community members not trusting this outside source of aid and further, will lead to a lack of cooperation.

With that in mind, the Lamqaddam and Habiballah recommended two focuses for our approach. They suggested our primary focus be to stress the safety improvements that will come from our project to the residents; the reasoning being that safety appeals greatly to everyone and is a common goal that can unite any community with an intervening outside organization. The second suggestion offered to us involved promoting community interest in the increased property value that frequently stems from rehabilitation. The Peace Corps representatives reasoned that landlords not living in the mellah may not be as invested or aware of safety issues in their homes, but that property value would gain their appeal. By these landlords contributing additional

money to the rehabilitation of their homes, their property's value will increase; all the while residents benefit from increased safety and higher living standards.

4.2.1 Urban Development

As mentioned previously, Mr. Hammadi outlined a distinct lack of funds available to be dedicated to the rehabilitation of homes in Rabat's mellah. In conjunction with the sentiment of Peace Corps representatives Lamqaddam and Habiballah that increased property value results in higher monetary contributions by residents towards rehabilitation projects, it became clear that urban development is a critical component to funding large-scale rehabilitation projects. With this understanding, further research was conducted on urban development strategies and examples are highlighted below.

4.2.1.1 Urban Planning Strategies

There are many organizations and urban planning strategies that work to rehabilitate important world heritage sites, one example being the Aga Khan Foundation (AKF) which works primarily in the Middle East and Africa. The AKF holds a firm belief that the deterioration of homes and other public buildings in a medina environment is a symptom of social and economic distress. The projects undertaken by this organization use housing renovations, social and economic development, and health education as a vehicle for economic growth. While surveying buildings, the AKF typically records not only structural information, but also data regarding the site's state of basic utilities, poverty, education, and the like. While the primary objective is always restoration, the AKF ensures that their work "provides means to achieve welfare" and

"creates a secure social and physical environment" (About the Historic Cities Programme, 2007).

In order to accomplish the goals outlined above, the AKF utilizes Integrated Area Development Planning (IADP). IADP is a process for development that treats a specific geographic area as a self-sufficient engine for rehabilitation and economic development and has four main stages that are implemented iteratively as outlined by Karam Sigh and Des Raj in IADP: Suggested Approach and Its Application (1978).

The first step of IADP is the "delineation of the area for planning." IADP dictates that the developing region should be small enough to be managed, but large enough that it can hold self-sustained growth. Second is the "study of growth indicators to identify the complementarities and lags in the developments of various services." This step focuses on determining what factors are holding back development. Once identified, action is then made to address or circumvent these issues. The third step entails the "identification of variables affecting development." This step works to identify all the variables that are involved in the development including social factors, physical variables, and anything else deemed relevant. It is at this point in time that any underdeveloped resources would be developed on their own before full area rehabilitation. The final step of IADP is the "development of services needed for full-scale area development." This stage focuses on establishing time constraints and doing all necessary work that benefits the target area. Appendix E contains a diagram of an effective development process.

4.2.1.2 Community Based Organizations

IADP and other large-scale urban development processes typically yield great results but due to the large scope there is a potential disconnect between the organizations and contractors doing the work and the residents being affected. In order to counterbalance this, residents can form a community based organization (CBO) as a way to influence the change and rehabilitation taking place. It is typical for governments and NGOs to provide planning, funding, and goals for urban development projects, however the residents are the ones most greatly affected by any change. The creation of CBOs ensures the success of projects because it increases communication between all project stakeholders. CBOs give residents a more unified and clear voice and inform the Government and NGOs of the community's goals and concerns. On top of this, CBOs encourage local economic development by providing opportunities for members to meet up and pool resources and skills (Belsky, 2013).

4.2.2 ADER-Fes

Urban development plans tend to focus on an holistic approach towards rehabilitation and the involvement of all stakeholders. Correctly planned urban development projects improve many components of life and generally improve the economic and cultural climate of a city. A strong example of an organization that maintains similar goals is ADER-Fes.

During a tour of Fes's medina, ADER-Fes representative Zouheir Hassan provided our team with significant knowledge about the scope of ADER-Fes and the level of its involvement in the rehabilitation of buildings in Fes. ADER-Fes is responsible for the rehabilitation of all 14,000 residences and historical sites in Fes, the largest medina in the world at 364 hectares (900 acres). ADER-Fes and its 70 employees work to restore

both public and private buildings alongside landowners and 120 distinct companies, and by providing a consulting service which recommends contractors to landowners, buildings are able to be renovated on a case by case basis. In order for these companies and contractors to be a partner of ADER-Fes, they must have an accountability system involving some type of insurance for residents as well as a timetable outlining deadlines for construction completion. Throughout the entire rehabilitation process of a site, the building's progress is checked daily by an ADER-Fes field representative. These daily visits ensure quality of construction and prevent rehabilitation from stagnating.

The process of private-home rehabilitation begins when an ADER-Fes representative visits the site and makes a structural evaluation. The resident is then provided grant money alongside recommendations for contractors. This grant money is typically no larger than 80,000 MAD ($8300) and is dependent upon the extent of damage evaluated during the initial structural evaluation. ADER-Fes representatives then monitor construction to make sure the grant money is well spent and the rehabilitation is successful. This year ADER-Fes is managing the rehabilitation of 500 residences and 27 historical buildings, and its continued efforts are helping more and more families every year. In order to manage such a large amount of buildings, ADER-Fes has a registered capital of over 45 million MAD ($4.7 million) (Qui Sommes Nous, 2015). Funders of ADER-Fes include the Moroccan government, The World Bank, UNESCO, and other independent companies.

4.2.3 Urban Development Options

There are many opportunities in the mellah for urban development. One of the simplest opportunities is the scenic location of the Mellah. One of its borders overlooks

the Bougreg River and Salé, providing what could become an attractive tourist destination. Another opportunity lies in the fact that rehabilitation efforts are still in their fledgling stages, which provides the chance for key stakeholders like local shop owners and residents to be highly involved in the creation and execution of the process.

One space for improvement by the prefecture is the tracking and documentation of collapsed buildings. The Prefecture possesses maps charting ruins of various extent throughout the medina, however, the maps conflict with each other and do not accurately represent the thoroughfares in the area.

A significant portion of documents given to us by the prefecture focused on the abandoned property lots in the medina. These abandoned houses were also noted during our guided mellah tour. The documents stated that the abandoned houses present the opportunity for new business or other creative uses of a currently uninhabited space. These spaces have high potential in two main areas: as marketplaces for local entrepreneurs or as tourist attractions in the form of cafes or hotels with prime location. Tourism presents a good source of revenue but, since residents don't have the capital to invest in hotels or cafes', these funds would likely go to outside investors. Alternatively using these open lots as spaces for markets would allow local shop owners to expand into larger businesses or newer facilities. This has a higher guarantee. A third option for the collapsed homes would be to reconstruct low income housing to alleviate the pressure of overcrowding in other homes. The downside of housing is the lack of additional revenue provided, meaning that the large capital required for construction would be a decaying investment.

4.3 Undertake a Case Study of two Houses

The largest pool of information gathered during this project stems from on-the-ground interviews and observations in the mellah. Site visits provided us with the opportunity to gauge mellah residents' interests and concerns with rehabilitation and supplied us with an in person look at the homes and structures our project is focused on.

4.3.1 Unguided Walkthrough

Before any official site visits were established, our group toured the mellah and made many observations, the most apparent being the high population density. The primary street, Rue Mellah, was narrow and packed with vendors selling vegetables, fish, and many other goods. In almost every case, the streets in the mellah are much narrower than the streets found in the rest of the medina. While walking down a particularly wide avenue along the side of the mellah, we came across two collapsed buildings; one had been completely cleared and the other was in ruins.

4.3.2 Guided Walkthrough

Our group gained a lot of insight on aspects of outside life in the mellah during our unguided walk through, but we agreed that in order to gain a closer perspective into the situation of residents living there, we would need a proper guide. Leading up to this visit, one of our primary concerns as outside researchers was appearing as a threat or as untrustworthy. During our guided tour, many residents approached us and volunteered their homes for inspection. This resulted in us obtaining a much larger sample-size of information on structural damage than we expected and simultaneously alleviated inhibitions about residents not complying with our requests. While each residence was unique in terms of damage, we found that damage in many structures share similar

sources. One example of this is new structural additions built above old structures. These additions add excessive amounts of stress to the walls of these homes, causing them to buckle outwards into the roads as shown in Figure 6. These bulges are typically not addressed on a structural level; instead cracks that form are plastered over allowing the degradation to continue.

Figure 5 Damage arch between two homes in mellah

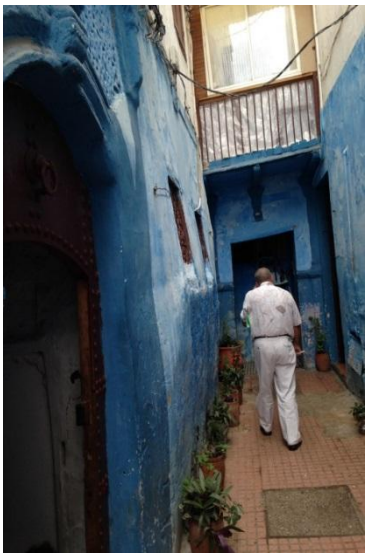

Figure 6 Bowed wall in the mellah

Some methods have been employed to help prevent walls from buckling outwards. Figure 5 shows a case where an arch has been placed between homes to transfer forces between two buildings and reduce risk of collapse, however, many of these arches have begun to display signs of wear in the form of cracks and bending. Combined with excess weight from additions, water leakage plays a large role in decreasing the structural integrity of buildings in Rabat's mellah. During winter there is increased precipitation which renders many rooms unusable as water leaks through the ceiling. This leakage furthers structural damage and exacerbates the risk of full or partial collapse. In Figure 7, a crossbeam has fractured in the center due to a

combination of water and insect damage. The majority of the ceiling in this case is made of untreated cedar timber and has undergone the same degradation as the crossbeam. Despite this broken crossbeam, the family continued to use the space as a bedroom until dirt and small bits of material began falling. For safety the family no longer uses the room except for a small space which they reserve for storage. Situations like this not only pose a risk of eventual collapse, but are also immediately detrimental to the quality of life of the residents. Without this bedroom the children now sleep in other rooms, thus making the home feel significantly more crowded.

Figure 7: Broken waterdamaged cross beam

In addition to residences, we were shown a number of abandoned lots where structures had either fully collapsed or reached an unstable state, rendering them uninhabitable. At the collapsed houses we visited, no significant effort has been made to remove the debris and thus the houses remain abandoned and condemned. In some particular cases, the ruins of partially collapsed buildings posed a hazard to nearby

buildings via their potential to fully collapse and fall into other structures. Many standing abandoned structures in the mellah are closed off and have signs warning against entry (Figure 8). These buildings pose a serious risk to the safety of residents and block potential foot traffic and transportation.

Figure 8: Left: a collapsed home. Right: a barred entryway to a collapsed building

4.3.3 Case Study Site Visits

The guided mellah walkthrough helped focus our research questions for the specific site visits conducted afterwards. The first site we visited was a one-story home located less than a block away from the outer wall on the Bouregreg river side. The owner had invested considerably in renovations of his home having expected them to be a long-lasting solution, but since the renovations were made, rain had begun to leak through the new roof and cause water damage in every room in the home. Water had deteriorated the ceiling in many locations, thus causing structural instability. The resulting structural hazard rendered three of the seven available rooms completely unusable during rainy winter months. One solution was to use corrugated fiberglass sheeting to help rain drainage, as seen in Figure 9. This method is cheap but needs to be replaced every two to three years due to sun damage and is not an effective long term roofing strategy.

Figure 9: Corrugated sheet in case study home 1

The walls of site one were recently renovated with cement, stucco, and sheetrock to protect against water damage. The owner explained that he used all his money on the first renovation, and that he had not been able to afford higher quality waterproofing for his roof. He completed most of the work himself with some hired help, however, he had no overall plan for the renovation and addressed each part of the house as he worked along. He did not provide a budget for how much money he would be able to spend to improve the roof, but what was clear was that if he does not fix his roof soon his first round of renovations will be completely ruined.

The second site is a home our team visited during our first guided tour which borders the outer medina wall alongside Avenue Hassan II. The site is three stories tall and is split between two families; the first two floors are a part of the original house built 70 years ago while the third floor is a newer structural addition built 16 years ago. The first family who lived in the home are the owners and reside on the top two floors. Another family rents from the first family and resides on the first floor.

Figure 10: A tree cracks through a restraining wall into the courtyard of case study home #2

On the first floor courtyard, there is a retaining wall roughly one meter offset from the medina wall that is filled completely with dirt, as seen in Figure 10. A tree is currently growing in this dirt and has caused cracks to form along the wall. A sapling offshoot and the roots from the main tree have also damaged the

floor tiling in the courtyard and the base of the retaining wall.

A shed-like structure was built as an addition to the first floor courtyard. This shed shares part of the ceiling of the main structure, with the remainder of the roof being a newer section. The new roofing on the shed consisted of wooden crossbeams supporting a layer of particle board and insulation surfaced with corrugated metal sheets. One of the crossbeams was visibly broken, and the particle board was badly warped from water damage (Figure 11).

Figure 11: Damaged roofing in added shed

Figure 12: Cracked third floor wall and a perpendicular supporting wall

Upon inspection, the stairs and walls on the second floor were uneven due to the superstructure shifting and sinking under the weight of the added third floor. The walls also showed signs of water damage and hollow spots on the walls were discovered when knocked on. The owners explained that horizontal wall cracks are not localized issues and penetrate through to the other side of the wall due to the shifting of the connected building (Figure 12).

During our visit, the added third floor had already begun to degrade despite the use of modern construction materials. The ceiling consisted of painted fiberglass fastened to wooden cross beams over a particleboard drop ceiling (Figure 13). The initially watertight fiberglass ceiling had begun to crack from heat and UV degradation leading to water damage in the walls and drop ceiling. The walls were constructed mostly of brick and plaster with concrete used for some walls and the second to third floor staircase. These concrete walls showed significant signs of instability with a number of cracks running horizontally, particularly in areas close to the ceiling.

Figure 13: Removed drop ceiling

4.4 Specific Upgrading Techniques Appropriate for the Mellah

By conducting site visits, our group was able to assess the damage and correspondingly apportion the sources of damage to two categories: water damage and structural instability due to the weight of additions. The following sections address these issues.

4.4.1 Roofing Methods and Materials

Homes in the mellah often have major issues with roofing which reduce the structural integrity of walls and lower the quality of life for residents. In order to help provide recommendations, our group found it imperative to look at both local roofing methods as well as global roofing methods.

4.4.1.1 Local Roofing Methods

Our group was exposed to core aspects of traditional Moroccan roofing technology during site visits as well as during a meeting with Mr. Hammadi. We learned that traditional Moroccan roofs have many layers. The bottom layer is typically a series of wooden cross beams laid underneath thinner wooden planks that are wedged tightly together. Straw or thatch is then placed on top of these wooden planks to provide

insulation, secondary waterproofing, and aeration for the roof. Above that is an approximately 25 cm (10 in) layer of earthen clay or dirt which provides further insulation followed by a thin paint-like plaster that acts as a waterproof layer protecting the rest of the roof. This pattern of roofing is common, but the materials and their application can vary based on price and availability. Wealthier homeowners generally construct the bottom layer with cedar, a durable and long lasting wood. A commonly used alternative to cedar is red pine, however while it is cheaper, red pine is a softer wood and degrades more quickly than cedar.

In addition to wood supports, steel I-beams are now commonly being installed between wooden planks to provide additional support. These planks are covered with up to 8 cm (3.1 in) of gravel and cement. The cement covering these supports is usually covered with thin paint-like plaster to serve as the waterproofing layer. This method in some cases is more structurally sound than the traditional method, but can be more expensive and is still vulnerable to water damage and collapse.

Other home construction efforts use corrugated iron or fiberglass sheet over crossbeams as a roof. Occasionally the corrugated sheet is painted with a protective layer. While these methods are not necessarily traditional, they are often used primarily due to their low cost. Pilot home #1 uses fiberglass to cover parts of the courtyard and provide shade and light waterproofing. In pilot home #2, fiberglass had been used as a major part of the roof construction and now has many visible cracks due to sun exposure. Low income areas like the mellah cannot afford to repair or replace fiberglass every two to three years as it deteriorates, and while a common alternative, corrugated iron, does not need replacement as frequently, it is heavy and is subject to rust and

breakage. Because of the faults in these commonly used materials, our group has researched newer, more effective roofing methods.

4.4.1.2 Global Roofing Methods

A variety of modern roofing methods have been developed and employed around the world in situations of varying economic and material availability. When exploring roofing options for application in the mellah, it is important to keep in mind price, availability, weight, repairability, and skill required for installation.

4.4.1.2.1 Waterproof Coatings and Paints

Waterproof coatings and rubberized paints, also known as Cool Roof Elastomeric Coatings (CREC), are waterproof substances than can be painted onto roofs. This paint coating is primarily used on flat roofs, but can also be used on corrugated sheet roofs, both of which are common in the mellah. The waterproof coating protects against "ponding," an issue often found in flat roofs when water fails to drain and pools in one spot. CRECs have numerous other advantages such as their ability to be applied with little or no professional experience, to reflect sun rays, and to last for up to 10 years (Choice Roof Contractors 2015). One price estimate for Sta-Kool, one brand option for CRECs, is 136 MAD per square meter ($0.26 per square foot) of roof coverage (The Home Depot). which is decreased when bought in bulk. While this price is competitive in the US and the UK it would prove too expensive for mellah residents without substantial aid. One detriment to this method is its inability to withstand foot traffic. As many residents in mellah/medina settings walk on their roofs, CRECs may not always be an appropriate solution. The availability of this product in Morocco is unknown.

4.4.1.2.2 Corrugated Fiber Reinforced Cement Roofing

Fiber reinforced cement (FRC) is a composite material composed of sand, cement and cellulose fibers, commonly comes in the shape of boards or corrugated sheeting, and is used for applications such as house cladding and roofing. FRC roofing sheets are typically corrugated in order to increase both the strength and the flexibility of the material. FRC is commonly used in areas subject to high fire risk, extreme temperatures, high moisture, and high sun exposure (Gibson, 2012).

There are many advantages to using FRC as a roofing material in Rabat's medina. FRC does not rot and is not damaged by insects which are common problems found with traditional wooden building materials. Additionally, FRC is highly resistant to temperature, sun exposure, water damage, and warping which makes it an ideal candidate to combat the environmental conditions of Rabat. Furthermore, the installation of corrugated FRC sheets is very easy compared to other roofing methods; sheeting can be fixed to roofs with simple fasteners.

Some disadvantages of using FRC for roofing include poor thermal insulation and poor sound insulation (Gibson, 2012). These poor insulation qualities make living conditions considerably worse for residents due to lack of temperature control. FRC is also not a traditional roofing method and will detract from the cultural heritage of the mellah by replacing original historic craftsmanship (assuming care is not taken to apply traditional finishings). Finally, FRC is not manufactured in Morocco and would be fairly expensive to import in large amounts.

The estimated price of FRC according to a United Kingdom supplier, Accord Steel Cladding Ltd., makes FRC economically impractical. Accord sells roofing sheets with a

six inch profile (15.2 cm) that are 3.54 ft wide (1.08 m) in varying lengths at a price of about 11 MAD per square foot (120 MAD per square meter)(Big 6 Fibre cement, 2015). Using an estimate of 1,300 square feet (120 square meters) for the area of a moderate sized medina roof the material cost alone for FRC sheeting would be around 14,000 MAD ($1,500). With a material cost this high before the cost of importing, transport, installation, and maintenance, FRC may not be economically feasible despite the numerous advantages it poses structurally.

4.4.1.2.3 Ethylene Propylene Diene Monomer

Ethylene propylene diene monomer (EPDM) is one of the fastest growing flat roof waterproofing solutions in developed nations, especially in the US and the UK. EPDM is made in thin membranes that can be applied to roofs by adherence, mechanical fastening, or loose laying, and is relatively lightweight, typically coming in thicknesses of 45 and 60 millimeters (1.8 to 2.4 in). This material can also handle the range of temperature changes that Rabat experiences, having been tested between -7 and 115 degrees Celsius (20 to 240 degrees Fahrenheit). An additional benefit of using EPDM is its ease of patching. If the membrane is ever punctured, this tear can be patched easily with sealant. In areas of larger damage, a new section can be spliced over the leaking section. EPDM membranes frequently come in white which helps thermally insulate homes and also prevents UV rays from damaging sections of roof under the membrane. Notwithstanding the above advantages, possibly the most compelling reason to use EPDM is its longevity. EPDM has been shown to last as long as 40 or 50 years without major repair or maintenance, thus making it a long term investment rather than a short term fix.

While there is a long list of advantages that promote the use of EPDM as a roofing material, there are many obstacles in the way of EPDM being a perfect fit for use in Rabat's mellah. To have a fully effective membrane applied, the installation of EPDM needs to follow precise procedures of cleaning, preparation, addition of insulation or primer layers, and finally sealing. This intricate installation process often causes EPDM to be too expensive for a low income area. As such, the material itself, while competitively priced in the USA and the UK, may prove too expensive for use in Rabat due to a lack of availability and local production. On top of their expense, these membranes can be punctured if they are exposed to frequent foot traffic, so roof access would be needed limited if an EPDM membrane were to be installed. Like other modern methods, EPDM membranes fails to maintain historical sensitivity (FAQS, 2015).

4.4.2 Wall Testing Methods

There are a number of standard tests that can be administered to determine the health of a wall. Simple tests can determine the extent of the damage and will allow contractors to decide whether a small fix will suffice or if more invasive work is needed. Many effective tests require expensive equipment which may be a prohibitive factor when deciding whether to do a test or not. The following segments outline methods available for testing the structural stability of walls.

4.4.2.1 Non Invasive Methods

While they typically provide rougher estimates of stability than more invasive methods, non-invasive testing methods provide quick and easy information on the stability of walls without damaging any property. Four examples on non-invasive tests

include infrared thermography testing, impact echo testing, ground penetrating radar testing, and acoustic emission testing.

Infrared thermography testing utilizes an infrared camera to create a thermal map of the wall and is typically used to test moisture levels inside of a wall. Because water has a different specific heat than most wall materials, thermal maps of walls with splotches typically signifies water damage (Cecire 2003).

An impact echo test is conducted by tapping a mechanically controlled steel sphere against a concrete or masonry wall. The impact sends a low frequency stress wave through the wall. As the wave propagates through the wall, it is reflected by any flaws. A microphone records the reflected waves, and the data are evaluated to evaluate discontinuities, holes, cracks, or other non-visible damages (Sansalone, 1998). A ground penetrating radar test is conducted in a similar fashion to the impact echo test. Ground penetrating radar tests use electromagnetic waves to locate holes, steel reinforcements, and other hidden qualities of the wall (Cecire 2003).

In cases where walls are especially prone to collapse, acoustic emission tests are can be administered. This test is for long term monitoring of a wall that can warn imminent. This type of test entails the placement of microphones directly on the wall. These microphones are used to pick up any noise emitted by sudden cracks or movements (Pielert, 1996). A specially trained professional is required to administer this test.

4.4.2.2 Invasive Methods

In cases where precise data are required, invasive methods can provide more useful information than most non-invasive methods. Two examples of invasive tests are stress measurement tests and in-place shear and flexural tests.

A tool called a flat jack can be used to measure the vertical stress and pressure of a wall. A gauge measures the vertical distance between two adjacent bricks. Mortar joints are cut and the the flatjack is lodged in between bricks in the wall. The wall will compress slightly after the mortar is removed, and the vertical distance between bricks decreases. The flatjack is then pressurized to expand the gap to the original distance. The final pressure of the tool is then calculated and used to measure the stress on the wall (Lab 6- Non-Destructive Evaluation).

In-place shear and flexural tests are commonly used alongside stress measurement tests, but are sometimes skipped due to the increased intrusiveness they pose. These tests entail removing a brick from a wall and a joint head from between bricks. A hydraulic ram is then fit in place of the brick. The force on the ram from the wall is then calculated and used to determine the wall's resistance to shear forces (Schuller, 1995).

4.4.3 Finishings

Architectural finishings are important toward the completion of rehabilitation and to preserving cultural heritage. The finishings implemented need to follow traditional styles in order to preserve and enhance the cultural value of a residence as well as the medina as a whole. While modern, non-traditional methods for construction may be necessary for safety reasons, surface finishings can still be applied to retain

cultural styling. The finishings detailed in this report focus on archways, doors, walls, columns, and finer decorations such as woodworking, plasterwork, and zellij. The main materials used for these finishings are wood, brick, plaster, and tiles.

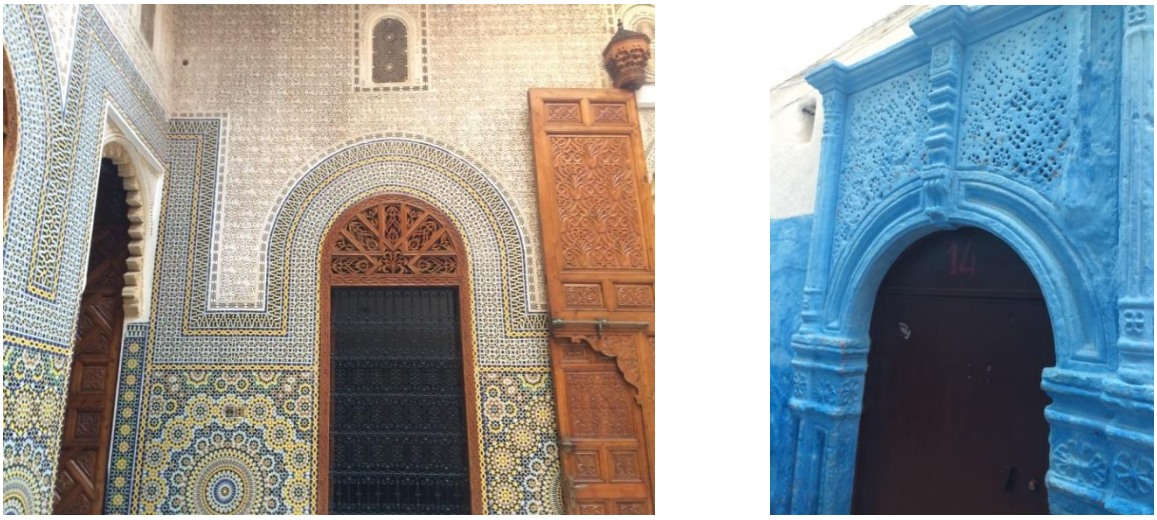

Figure 14: Left: A typical mellah entryway. Right: Dar Merini, a rehabilitated medina house

The entryways to homes in Rabat's mellah commonly have a decorative archway. The most prevalent style seen in the mellah follows the design seen in Figure 14. This archway is part of a facade that mimics columns surrounding the door and contains many decorations including flower and star patterns. These archways are typically painted with a bright color like blue or an earthen color like tan. Many houses in the mellah do not have entryway architecture like this and adding these to houses can raise that value of residents' homes and add character and variation between buildings.

Figure 15: Left: Fine woodworking on privacy wall. Right: Door in a fonduq in Fes

Wooden finishings are most commonly carvings, doors, or window frames. Wood carving is an artisanal craft that can be seen in virtually any wood material used in a house. Fine wood carvings can be seen on the doors and windows in Figure 15. Original wooden fixtures can be damaged over time but can often be repaired or salvaged instead of scrapped completely. In one rehabilitated fonduq in Fes, an original wooden door was used but new pieces of wood were used to replace damaged areas as seen on the door in Figure 15. In another fonduq, original wood was recycled by sanding off damaged sections, re-carving them and then re-staining them. The same fonduq had many wooden beams that had become too damaged to be used structurally, so they were repurposed to cover I beams that were providing structural support in the walls. Repairing or repurposing wooden materials in houses is practical and preserves traditional styles and materials but wood carving can be incredibly time intensive and

requires highly skilled labor. This may not be economically feasible for low income rehabilitation projects.

Figure 16: Left: Workers mixing mortar. Right: Fresh mortar on old bricks.

Walls and columns are commonly finished with a mortar made of sand, lime, water, and other additives. Figure 16 shows the creation of this mixture by contractors working with ADER-Fes. An original brick wall and stone columns can be seen being finished with this plaster in figures 16 and 17 respectively. A lighter plaster is often applied on the surface of walls which can be carved into intricate designs. This plaster carving is a traditional art form which can be seen in Figure 17 Plaster carving, much like wood carving, requires large time investments of skilled labor that may be too expensive for projects that are not large scale public buildings.

Figure 17: Left: Plaster on old stone columns. Right: Intricate plaster carvings in Fes

Zellij is an historic Moroccan tile mosaic crafted with meticulously hand cut pieces placed in complex geometric patterns. This beautiful craft is widely considered an art form of its own and is known only by master craftsman. Zellij can be seen on walls in figure 18. Zellij tiling is a unique and classic Moroccan art which is in limited supply in the modern world due to the expertise and vast quantities of time required for production. Unfortunately these limitations of skill and time consumption make zellij rare and expensive and will be difficult to include in rehabilitated homes. Alternatively, renovated homes in Morocco display faux zellij, of tiles that have been painted in similar geometric patterns to traditional zellij. Imitation zellij can provide a similar aesthetic experience for much less monetary cost, but loses the benefit of supporting local craftsmen.

Figure 18: Left: Faux zellij. Right: Zellij in Dar Merini

5. Conclusions and Recommendations

Throughout our study a number of issues became apparent, some within the scope of our project and some outside but directly linked. Our methodology and findings were focused on discovering and searching for solutions for these key issue. The following recommendations address those issues which are in our project scope and suggest options that may lead to solutions for issues outside of our projects focus.

5.1 Case Study Recommendations

During our site evaluations, we focused our efforts on learning about two things: building information (with two subsets: structural data and finishings) and social information. This focus lead us to a set of recommendations that focuses partly towards the rehabilitation of our two case study homes and partly towards implementing a consistent approach for the evaluation and planning of damaged homes on a large scale.

5.1.1 Structural Recommendations

It is important to preface the following segment with one critical observation. Due to the case-by-case nature of damage in the mellah accompanied by the highly technical issues faced by roofing and walls in each structure, it is crucial that a trained architect/engineer visit each residence and make an official evaluation before any work begins. While organizations like ADER-Fes do conduct some initial vision planning, all architectural and engineering work is left to professionals trained in that capacity. Recommendations on specific upgrades and plans for these case study houses are thus past the scope of this project. That being said, the identification of large scale issues and the corresponding possible solutions is within the scope of our project.

Both case study homes one and two as well as many of the homes shown on our initial guided walkthrough suffer damage primarily related to water. We recommend that roofing be the first priority in any reconstruction effort undertaken in Rabat's mellah. Prioritizing proper roofing will help prevent water damage in homes and in turn will improve the quality of life of the residents.

Reapplication of traditional methods of roofing as seen in case study home one most accurately preserves historic elements of the medina. However, the integration of modern methods can lead to quick degradation, as seen after only three years in pilot home #2. Water resistant materials and coverings when improperly applied can seal moisture into a traditional aerated wall, causing significant damage. Due to this, we recommend that modern methods and traditional methods rarely be used in combination and only with the specific approval of a trained engineer.

Other homes which have already forgone traditional roofing construction, like pilot home #2, provide an opportunity to use new roofing methods. For these homes, we recommend that modern methods be used but traditional finishings be applied to maintain historical relevance. We recommend modern roofing methods because, despite their break from tradition, the pose a durable long lasting solution and generally are easier to repair unforeseen conditions cause damage. Possible options for modern roofing materials are FRC or corrugated fiberglass with a CREC, but due to the expense of both of the options, other unexplored methods may need to be considered.

In many homes visited, particularly pilot home #2, walls are not structurally sound and pose a risk of collapsing. Given that the walls are already heavily damaged, non-invasive testing is advised. One example of a damaged wall is the retaining wall in

the courtyard of pilot home #2. The owners of the house, in conjunction with a trained engineer, should discuss whether the wall has any structural purpose. Removing the wall, the dirt, and the tree is a viable option that would increase the space in the courtyard and prevent any possible future damage to the house and city wall.

5.1.2 Finishings Recommendations

Finishings provide the opportunity to stick to tradition when otherwise history may have to be sacrificed for safety. Our broad recommendation for finishings is to keep as many traditional fixtures as possible and use finishings to add cultural and aesthetic value to homes in the mellah. As PC representatives reminded us, it is important to gain the interest of residents we plan to aid. By including finishing components in a rehabilitation strategy, residents will feel that not only are their basic needs of shelter being addressed, but they are also gaining a more comfortable and pleasant home. Many finishings like the plaster carving in pilot home #1 add relatively little expense to renovation, but do result in a visually impactful improvement.

We also recommend that an effort be made to employ local artisans and craftsmen in the creation of finishings. By hiring local workers to accomplish this work funds used for renovation will continue to circulate through and improve the mellah and surrounding areas. Hiring local artisans also increases demand, making it more likely that unemployed people will be able to learn and use these skills from already skilled workers. This simultaneously employs those without work and helps prevent artisanal crafts like zellij and woodworking from vanishing.

Finally, we recommend that the planning of finishings for a home heavily involve the residents who currently live there. Fully engaging residents in the finishings

planning will bring residents deeper into the rehabilitation process and give them the opportunity to pursue features that otherwise may not be considered.

5.2 Organizational Recommendations

We recommend the implementation of an agency that can supervise and correctly coordinate funds (and their acquisition), contractors, residents, and prefecture efforts. Continuous effort is required to properly balance these factors, and more importantly, this effort cannot be properly provided by interim workers such as outside consultants or researchers. While the Prefecture of Rabat is a currently standing organization interested in the rehabilitation of structures in the medina, it is not properly equipped to handle this workload as there is not yet the manpower or resources available.

Based on our research and assessment of Rabat's medina, this new organization needs to be able to accomplish three main objectives: secure funds, assess structures and create plans for their rehabilitation, and verify builders' credentials and ensure progress on their assigned projects.

5.2.1 Funding

While the creation of an ADER-Fes like agency in Rabat represents promise towards the future state of structures in Rabat's medina, such an agency cannot be formed nor operate without a firm economic backing. ADER-Fes currently has 45 million MAD ($4.7 million) dedicated for project use, and the amount of money they have set aside compared to the scale of their work accurately reflects the amount of money needed on a per-residence basis in Rabat.

While urban development, discussed later, provides a local boost in the economy and can provide money for rehabilitative efforts, it does not provide nearly enough up

front capital to support large scale rehabilitation projects. ADER-Fes circumvented this issue of funding by reaching out to organizations such as UNESCO, The World Bank, and other NGO's for funding. We recommend that the Prefecture of Rabat do the same.

5.2.2 Community Driven Rehabilitation

During our site visits and mellah walkthroughs, it was apparent that mellah residents have a strong desire for their homes to be fixed. This enthusiasm can be harnessed to reduce the resources needed to survey all the houses in the mellah. Housing renovation request forms should be created and made publicly available in easily accessible locations. By submitting these forms the residents can officially notify the organization that their house is in need of repair. The forms should include space for residents to give the location of their home as well as contact information. The main section of this form should be a questionnaire that residents can use to report the type of damage in their home they would like to have addressed.

5.2.3 Social Team

We recommend that this new agency tasked with supervising and coordinating rehabilitation efforts include a social team branch. This social team would be responsible for housing renovation requests, and would complete the initial review of the house. Additionally, this social team would work directly with the residents throughout the rehabilitation process and would focus primarily on creating a trusting relationship with the residents. As stated in our methodology, we chose to avoid many sensitive questions despite the potentially valuable information we could have gained. This social team would not have this handicap.

One important example of sensitive information that this team could obtain involves the residents' ability to fund rehabilitation. Sub-questions may include whether the members of the family have stable work and income, if the residents are willing or able to pay, and if they need a subsidy or loan to cover the construction. This information would be recorded by the social team in a standard organized form. Given the informal culture we have observed in Morocco, this information might need to be collected through conversation rather than by handing the residents the form. That being said, an effective social team should simply be able to give residents the form to fill out in their own time.

Like the social team in ADER-Fes, this new team should also conduct initial evaluations of residences. This evaluation would be multifaceted. First, the house should be given an initial degradation ranking (urgency ranking). Potential rankings could be:

- Urgent damage/ruin
    - Home is in serious risk of collapse. Multiple walls or ceilings are seriously damaged. Multiple rooms are avoided for safety.
- Heavy damage
    - Home shows heavy damage. One or two walls or ceilings are show major cracks or bends. Some rooms are avoided due to safety or water leakage.
- Medium damage
    - Home shows some damage. Walls or ceilings have minor cracks or are starting to deform. Some rooms leak during heavy rain.
- Slight damage

    - Home shows mild damage. There are signs of cosmetic damage, chipped paint, broken tiles, or poorly installed renovations.
- Minimal damage
    - This type of house only needs general maintenance work.

Secondly, a general evaluation should be made which catalogues damaged sections of the home. The social team should create a floor plan of the house and label each affected area of the house with a number or letter. Pictures should be collected of each damaged area and labeled with correlating numbers or letters followed with basic recorded observations such as:

- Roof damage in x rooms
- Includes ad hoc additions
- Wall damage in x number of locations
- Most significant threat is x

5.2.4 Contractors and Artisans

Like ADER-Fes, this new agency should work with trusted and approved contractors and artisans. We recommend that this agency uphold stringent quality regulations to ensure that housing renovations are high quality and positively impact houses rather than causing more problematic ad hoc renovations.

Provided with the initial evaluations from the social team, associated contractors would first provide a more detailed evaluation of each hazard in the house. This evaluation should determine the extent of the damage to the house and subsequently outline the proper methods necessary for full rehabilitation. We recommend that

artisans work closely with these contractors and residents so that they can provide the residents with affordable and traditional finishings.

5.2.5 Adaptations for the Mellah

While the model of rehabilitation in Fes is widely applicable to rehabilitation in the mellah, a few key factors require changes for the implementation of an agency of Rabat. One main difference is the size of the affected area. ADER-Fes covers an area of 364 ha of medina territory, the mellah is less than a tenth of that size, which grants some opportunities not present in Fes. By working in a smaller area this organization will likely deal with more cases in more focused areas. Due to this density of projects it is likely that some projects can be combined to provide a more effective solution for more homes. The organization created for the mellah can also focus on knowing and understanding individual resident concerns. Personal interviews and discussion in favor of exclusively forms, will help keep residents involved and ensure that renovation projects stay on course and are seen through completion.

5.3 Urban Development Recommendations

As mentioned previously, the Aga Khan Foundation firmly believes that the deterioration of homes and other public buildings in a medina environment is a symptom of social and economic distress. This belief leads The Aga Khan Foundation to implement rehabilitation projects are typically used as a vehicle for wider economic growth. Similarly, during our interview with the Peace Corps in Rabat, we learned that improving property value can have a large effect on homeowners' willingness to contribute to rehabilitation projects. With that in mind, we recommend the prefecture investigate options to generate local revenue and increase property value such as

creating and introducing new businesses in the medina, create training opportunities for residents, and involving the community in all previously stated goals.

5.3.1 Uninhabited Properties

In our findings we learned that many properties have been uninhabited for years. Some of these houses have already collapsed, while other houses were deemed too dangerous for habitation. As stated in citywide evaluations provided by Mr. Hammadi, these areas can create huge opportunity for new businesses and can generate significant revenue to assist in funding rehabilitation projects. We recommend that the Prefecture of Rabat utilize these lots to assist in the funding efforts of rehabilitation projects.

There are a number of potential avenues of development that should be investigated. First, if possible, the current ownership of the land should be determined. In the case that the owner can be contacted, the prefecture should either ensure a commitment of investment and development from the owner or negotiate for the ownership to be transferred to the prefecture. In the absence of a clear owner, the prefecture should investigate the legal grounds to claim ownership of the land. At this point the prefecture would have the opportunity to auction off the abandoned housing lots to businesses. These businesses should be obligated to clear out ruined structures and/or renovate still standings hazardous structures. During the building process the business should also be required to follow a stringent building code, to ensure the longevity and safety of the new buildings, and to include traditional building aesthetics in the design. If the prefecture follows this option then they will have created a source of revenue that only requires minimal investment. However, with some initial investment the prefecture, or the agency created by the prefecture, could take charge of clearing out

the ruins and renovating the current structures. This is more expensive upfront, however the property value would increase significantly. The sale of the property would provide even more towards the citywide rehabilitation efforts.

5.3.2 Skills Training

Every aspect of the rehabilitation project is an opportunity for job creation. IADP encourages the development of skills within the community and the use of locals to complete the rehabilitation process. Artisans and contractors companies can all be staffed by medina residents if given the proper training. Additionally, new businesses that work enter the medina should be encouraged to hire and train locals.

5.3.3 Developing Community Based Organizations (CBO)

The prefecture should work with community leaders to encourage the development of CBOs. Resident involvement in rehabilitation is crucial and our findings show that CBOs can convey the concerns, desires, and needs of the involved residents to the government. CBO leaders should function as intermediaries between the government and residents in order to simplify the coordination of all key stakeholders.

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Appendices

Appendix A. Peace Corps Interview Questions

Are there any Volunteers working on projects in the medina, including the mellah?

Are any of the projects focused on entrepreneurship or business?

Do you work with community organizations or committees?

Who leads those committees?

Are there projects related to housing renovations?

What are some benefits to working with Moroccans?

What are some challenges to working with Moroccans?

Are there any NGOs in the area that contribute to projects in Morocco?

Is there any collaboration between the PC and the Moroccan Government?

- If yes, on what kinds of projects?
- Else, is there interest in collaboration or has there been any communication/outreach?

Is there any collaboration between the PC and local NGO's?

- If yes, on what kinds of projects?
- Else, Is there interest in collaboration or has there been any communication/outreach?

What are some successful projects from the PC's long history in Morocco?

What have been some of the largest obstacles for PC projects in Morocco?

What have been some of the largest obstacles for the Moroccans involved in PC projects?

What types of projects in Rabat do you do?

Is our project the type of thing PC would get involved in?

Appendix B. Social Oriented Site Visit questions

The non-sensitive questions:

How many families live in this home?

How many people are in each family?

How long have you lived in this home?

Do you have family in the area?

Do you have concerns about pursuing repairs?

What types of obstacles have stopped repairs?

- Do you know of contractors or builders in the area?
- Are you confident in repairs that you make?

Who do you think should be responsible for funding repairs?

Would you be willing to invest in repairs?

What are your hopes for the rehabilitation of your house ?

What are your fears or concerns with the rehabilitation of your house?

Questions we decided were too sensitive to ask. These questions were not asked outright, however we still tried to attain this information:

- Would you trust contractors or builders from the area?

How many people in each family:

- Work
- Attend school
- Stay at home

Do you work in the area?

What's your occupation?

Do any of the families living here own this home?

Do you have frequent contact with the land owner?

Does the landowner know the state of the building?

Do you plan on staying in this home (as long as it's safe)?

Do you plan on staying in the mellah?

Appendix C. Structural Site Visit Questions

What do you see as the most important fixes/upgrades for your home?

Have you or the owner made repairs recently?

Have you or the owner made additions recently?

How much construction or repair knowledge do you have?

Would you be interested in learning other repair methods?

Appendix D. Value Sharing/Value Capture

Often in low income areas in developing nations property tax does not bring in substantial revenue for the government. Either the governments do not try to collect the tax, or residents resist paying it. Value sharing is one way to improve the situation. The goal is to make small investments in local infrastructure that can increase property value. The Government can use increase in services as justification for increase in property tax, and the residents are more likely to pay. Additionally the government can increase price on upfront sales of land as a result of the increased value. This money can and should be used to further rehabilitate houses and develop amenities in the neighborhood. The success of value sharing can be improved if the government can sell public spaces and vacant lots to private owners and businesses (Belsky, 2013).

Appendix E. Development process diagram