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Getting Design and Construction on the Appropriate Track: A Structural Case Study

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Good morning everyone.
Welcome to Getting Design and Construction on the Appropriate Track.

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Course Description

This course is a case study of EMI Uganda's partnership with Congo Initiative (CI) through the development of their university campus, UCBC.

We will explore why CI is a great ministry partner for EMI and outline the different stages of EMI's involvement at the UCBC campus. We will focus on the community center building and analyze the problems with the initial design and construction, identifying the key factors that led to those problems, discuss EMI's structural assessments and recommendations, taking note of how the context of the project influenced the recommendations.

Finally, we will walk through the stages of demolition and reconstruction, noting the unique challenges of the context.

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Learning Objectives

1. Discover why contextually appropriate design and construction solutions are needed to ensure project success.
2. Discover how culture and context affect the priorities of safety, risk, cost, and timeline.
3. Explain the challenges of construction in a remote, developing world location.
4. Discover what makes a great partner ministry for EMI

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Introduction

Professional
B.A.Sc. in Civil Engineering from University of Waterloo, Ontario, Canada
Ontario Licensed P.Eng.

EMI
Intern in UK Office 2013
Volunteer in Uganda Office 2013
Joined Staff in 2014
Engineering Manager, EMI Uganda

Family
Married to Ashley in 2015
Joshua born 2016
Abigail born 2018

My name is Matt Lammers.
I am Canadian, licensed as a engineer in Ontario.
I have been with EMI since 2013, as an intern, 1 year volunteer and now as staff. I am currently the engineering manager at EMI Uganda.
I am married with two kids.

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Why does EMI exist?

- To develop people, design structures, and construct facilities which serve communities and the Church

Why does EMI exist?
Here is our mission statement.
One way we fulfill this mission is partnering with other ministries, filling in the gap that they cannot do themselves.
Most ministries have little to no experience with building or site development. They don't know the process involved or the questions to ask. The have a vision but don't know what it takes to make it a reality. We play a key role in helping ministries realize the vision God has given them.
We will focus on one ministry partner of EMI Uganda.

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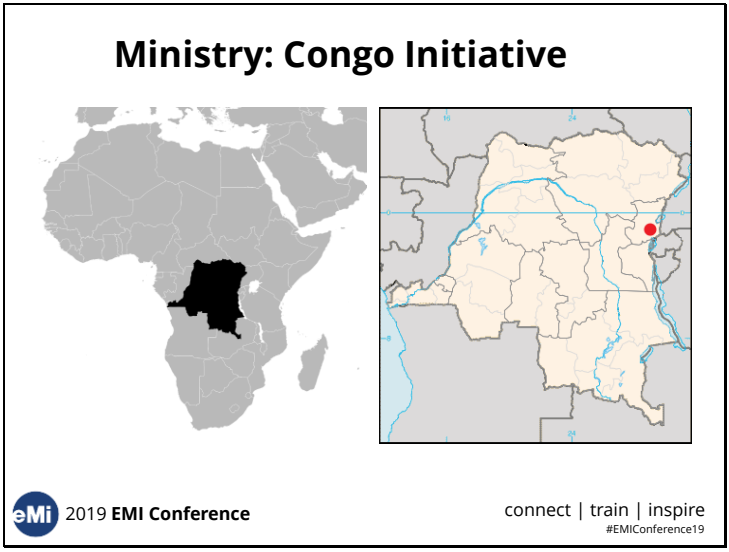

EMI Uganda has partnered with Congo Initiative since 2012.
DRC is located in central Africa. It is ¼ size of US, 2nd largest African country and about 90 million people. It is one of the richest countries in natural resources but ironically one of the poorest.
Congo Initiative is located in Beni, DRC, 50 miles across Uganda border

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Ministry: Congo Initiative

In August 2002, at the height of war in DRC, 13 Congolese men and women – leaders representing churches, educational institutions, health services, and government – gathered in Beni to pray and wrestle with three questions:

- What has happened in our country?
- Where has the church been?
- What are we going to do in response?

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Congo Initiative was born out of the Great African War, which is estimated to have cause 5 million deaths, as Christian leaders gathered to ask themselves 3 questions:
What has happened to our country?
Where has the church been?
What are we going to do in response?
Congo Initiative established as a response to these questions. The core program of CI was determined to be a university, UCBC The Christian Bilingual University of Congo, as a way to distinguish itself from all the other NGOs operating in the country. It was also a way to make a statement that CI was firmly rooted in the community, a part of the community, an answer to the community's challenges rooted in the context of the community. CI is not an outside entity imposing outside practices and paradigms.

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Ministry: Congo Initiative

- Congo Initiative educates ethical leaders who have integrity; invests in a sustainable vibrant Congolese society; and develops grassroots initiatives for peace, hope, and justice.
- Motto: being transformed to transform.

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One of the major problems in Congo is a lack of leadership. The vision of the university is to develop leaders with godly values who will go out and transform society. This is seen in their motto, being transformed to transform. We are not changed for ourselves, but to impact others.

Some of the reasons that I am excited about our partnership with Congo Initiative are:
This grand, compelling vision of national transformation through discipleship of leaders
It is a holistic ministry, reaching out to all parts of society
It is an indigenous ministry, established and run by Congolese, but they are also connected with international partners help achieve this vision. This is where EMI has come in.

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EMI Uganda Involvement at UCBC

- 2012 Master Plan
- 2013 Structural Assessment
- 2014 Structural Assessment and Redesign
- 2015 Demolition
- 2016-2019 Remediation and Reconstruction
- 2018 Master Plan Update

EMI's involvement at UCBC started the way most of EMI partnerships do, with a master plan.
It the shifted to focus on the community center building, which is the focus of this case study.

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Here is the original master plan. The site is 85 acres. The full build out capacity of the campus is 3000 students. There is a creek running through a ravine in the middle of the campus, with academic buildings on the east and residential buildings on the west.
The centerpiece of the campus is the community center, located at the heart of the academic buildings.

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Here is the community center at the time of the original master plan. The building was partly constructed, though construction was put on hold due to lack of fund. Many spaces in the building were being used, though unfinished. We will talk more about this building.

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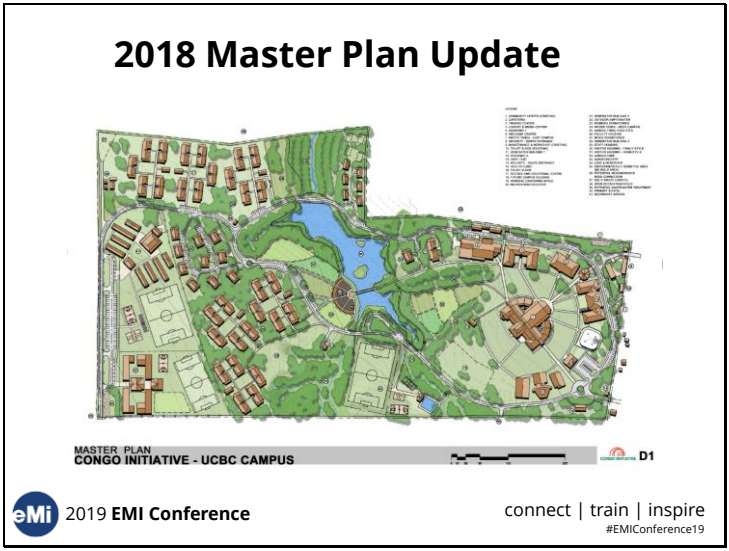

Last year we worked with UCBC to update the master plan.

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EMI Core Values

Design: EMI works within the local context to design and construct culturally-appropriate facilities that are sustainable, affordable, and transformational.

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One of EMI's core values is design. EMI works within the local context to design and construct culturally-appropriate facilities that are sustainable, affordable, and transformational.
I want to focus on the local context in the case study.
Why do we need to know the local context? Can't we just use our professional skills and experience to design?
We will see through this case study, what happens when local context is misunderstood and what was done to correct it.

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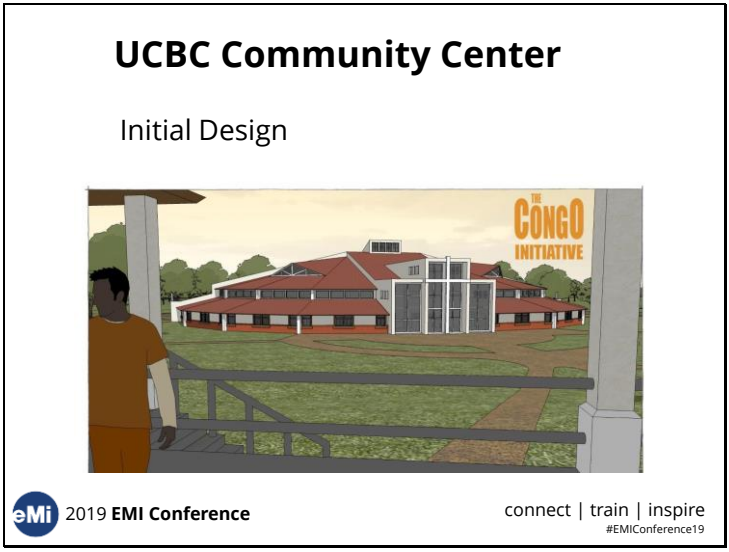

As mentioned, the community center was not designed by EMI. A US Architect firm in Midwest donated the arch and struct design. We appreciate the effort, and though it was well intentioned, it lacked local knowledge and ended up costing a lot of time and money

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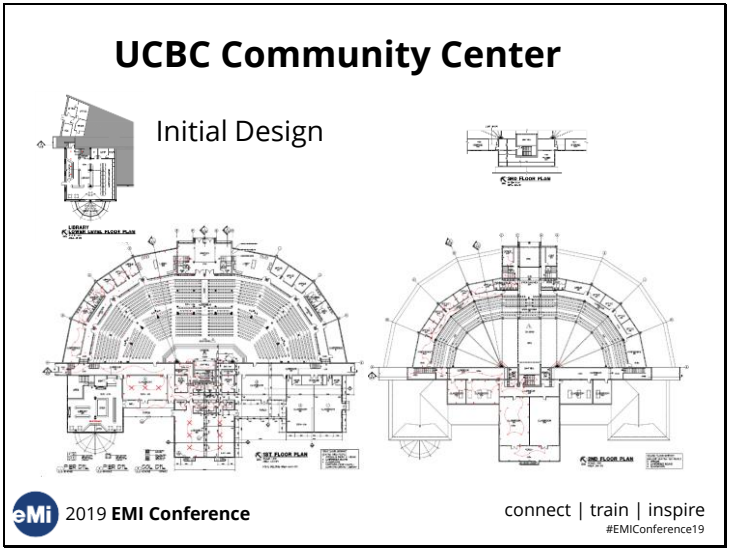

Here is the original plans. There is a partial walk out basement, two main levels and a small upper level. The building dimensions are approximately 300’ long and 200’ deep. The capacity of the auditorium is 2000 seat on the main level and 700 on the balcony.

Some of the issues with the design are poor natural ventilation and lighting, especially in the auditorium and the interior spaces. This would necessitate mechanical ventilation to make some of the spaces comfortable. While this is common practice in the states, it is not in Congo where electricity supply is inconsistent. Another challenge with the auditorium is the poor sightlines in many areas due to the balcony columns.
The drawings had insufficient detail to build from, lack of dimensions and construction details.
Building terminology can vary around the world. What would call the 1st floor above grade? 2nd floor. In DRC and Uganda it is the 1st floor. The drawings use American terminology.

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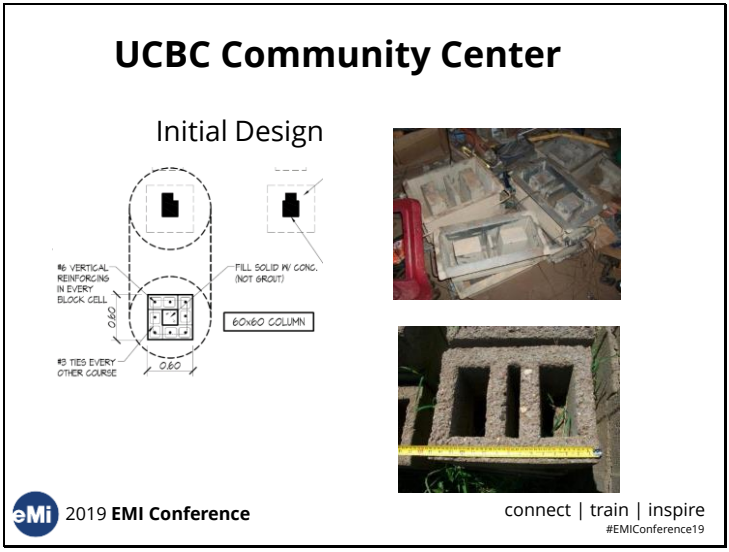

Here we see a structural detail. Some things to note are the use of concrete masonry unit, a masonry column and the rebar sizes, #6 bars and #3 ties.

Concrete masonry units are not locally available or used. So they were fabricated specifically for this project resulting in variable, and often poor, quality.

Since CMUs are not available, masonry columns are new. The attempts to grout the columns with concrete resulted in many voids.

What size is a #6 bar? ¾ or 6/8 of an inch. This is a US rebar size. The locally available bars are 10mm, 12mm, 16mm. #6 is 19mm. In one instance, 12mm bars (approximately #4) were installed instead of #6 (19mm)

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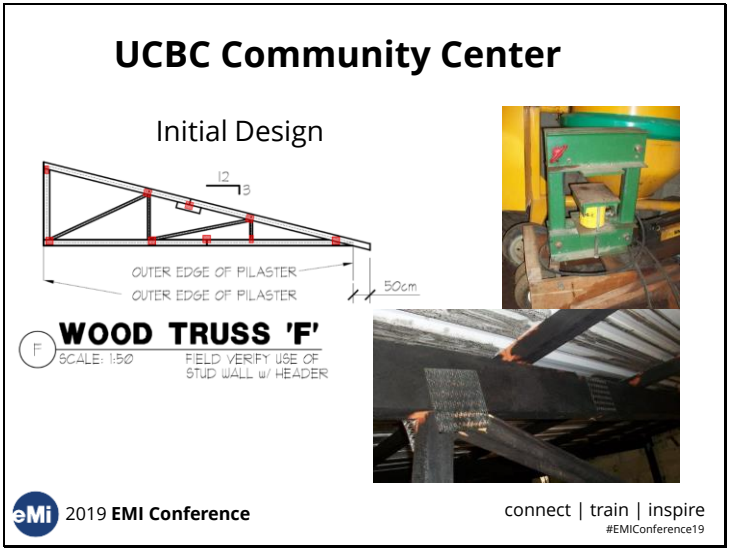

Timber truss connector plates are not available so they were imported from the US, typically not a great solution when something unfamiliar needs to be imported.

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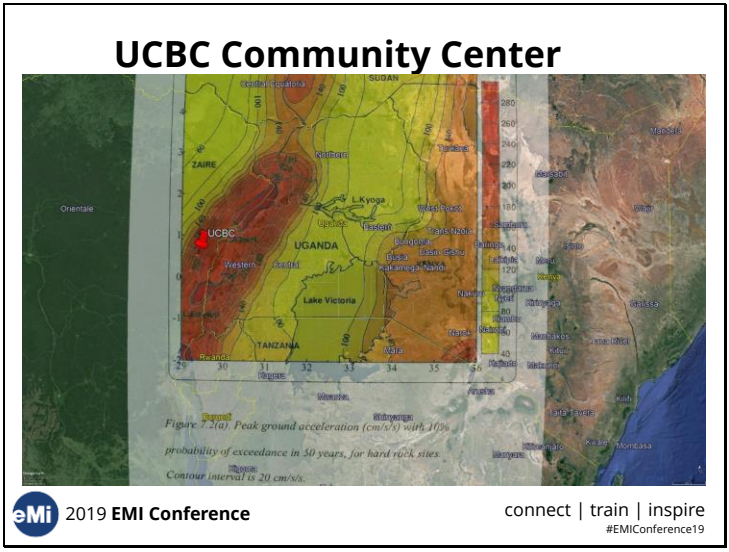

The structural design did not seem to account for seismic. Here is a peak ground acceleration map for the area, Beni has 25%g Peak ground acceleration 10% probability of exceedance in 50 years, 1 in 475yr return period. The highest recorded earthquake in the area is a 7.0 magnitude.

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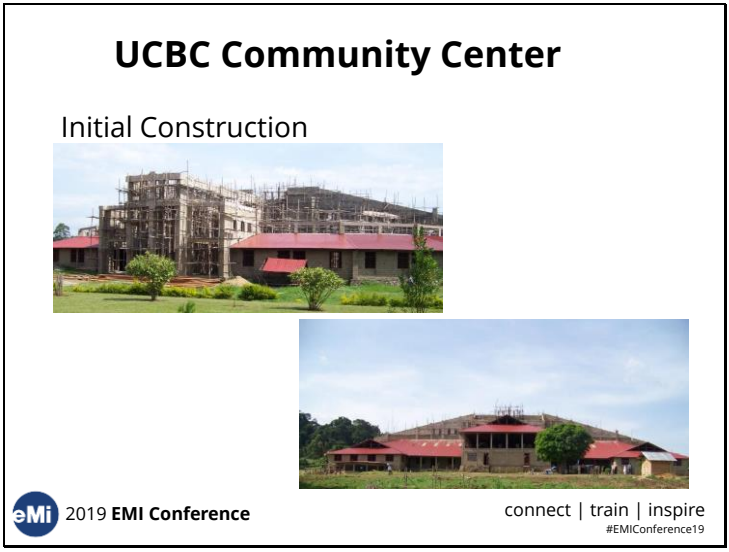

We will now turn to the challenges with the initial construction.
There was insufficient, experienced construction supervision. The supervisor split time between this building and other projects, then finally left leaving his assistance in charge.
The scale of this building was larger than the experience of the workforce.
New construction techniques used (CMU, truss plates, masonry columns)
There was no material testing of concrete or masonry units.
Since the design team was remote and only visited periodically, when construction didn't follow the design intent it was noticed months later and hard to rectify.

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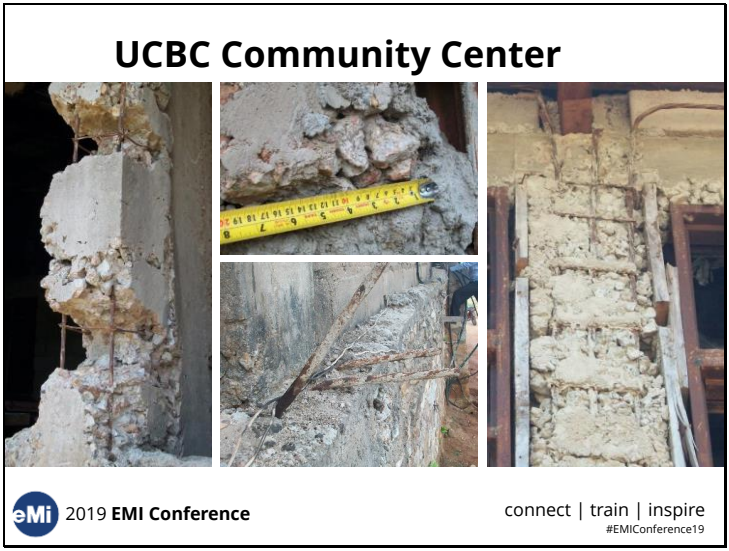

We will look at some pictures of the original construction to get an idea of the quality and issues.
What is wrong in these pictures?

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Here we see the challenge of building a larger scale than what is typical for local construction methods.
There balcony beams are 3’ deep beams but the formwork wasn’t braced enough and the face of the beams aren’t flat. The construction team learned and this problem improved on further beams.

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UCBC Community Center

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The longitudinal bars splice is not within stirrup cage.

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Notice beam sag

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UCBC Community Center

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Concrete beam has been poured in layers, it is poorly bonded and the top is poorly consolidated.

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UCBC Community Center

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Notice architectural feature of a window at top of column.
What is harder to notice in this picture is the sag in girder truss. And ceiling not yet installed

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UCBC Community Center

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We have seen a snapshot of the issues throughout much of the building. One thing this highlights in the importance of understanding who is going to build the project and designing within their capabilities. The expertise to construct a building of this scale was not available locally.

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Structural Assessment

Desktop study of design drawings
Initial Site Visit, condition worse than anticipated
Second Site Visit, demolitions and remediation

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Construction had stalled until new funds secured. Then CI invited EMI to assess the building to determine the best way forward.
We started with a desktop study of the design drawings and a review of the design team's correspondence with the construction team. We knew of several issues to investigate on site but once we arrived the condition was worse than anticipated, which resulted in a second trip to assess the structure further to determine the path forward.

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Structural Assessment

Why not tear the building down and start again?

Recommendations:

- Qualified Construction Management
- Detailed construction drawings
- Demolition of auditorium
- Redesign of auditorium
- Remediate rest of the building

As you see these picture and hear about all the challenges you may be asking why not tear the building down and start again?
Here are some of the considerations as made our recommendations:

- Cost
- Complexity of construction
- Safety, which raises an interesting question – how safe is safe enough? And what building code should we use as with many developing countries, DRC doesn't have building code? When we deviate from code, how do we define what is an acceptable level of risk? Who should define this? What is acceptable in your mind is different than what is acceptable in my mind because I have worked in Uganda for 6 years. What is acceptable in my mind in different than what is acceptable to a Ugandan. This is question we are wrestling with frequently.

- A final consideration is advancing the mission of the ministry. How do we design and construct in a way that furthers the vision to connect with and transform the community and the nation.

Investment by the community was key factor in our recommendation as the ministry wants to be part the community. The local community had donated materials and labor, and there was a sense of community ownership as a result.
The philosophy we took was to keep what could be reasonably fixed, demolish what could not

Advance slide
Here are the recommendations:

- They shouldn’t proceed until there is adequate construction management in place.
- More detailed drawings were needed for construction. There is a cultural consideration in this as well. Since it is the designers job to designer and the contractors job to build. It would be shameful for the contractor to question the design. For the designed because he should have included the details and for the contractor because he should be able to build it.
- Due to the scale and design issues with the auditorium it needed to be demolished. Then redesigned.

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Congo Initiative's Response

- Hard news to receive
- Took several months to respond
- Demolition would be demoralizing to community
- Accepted our recommendations
- Committed to walking with EMI through the process

- During our assessment trips, there was a lot of hope surrounding our presence. The underlying thought was the engineers are going to fix our building. It weighed heavy on us to see the poor state of the building amid the optimism.
- Due to the community investment in the initial construction, demolition would be disheartening for the community. Congo Initiative's explanation to the community was that they value the community more than money. They want a safe, quality building for the community which strengthened the relationship.
- After time to process the recommendations, CI accepted our recommendations and invited EMI to come and redesign the building.

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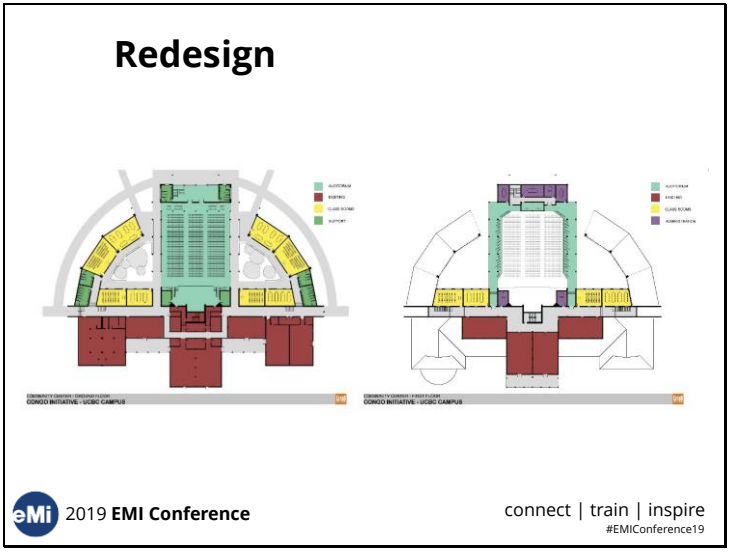

Here are the redesigned floor plans. The auditorium capacity was reduced from 2700 to 1000 people. It was separate from the wings to create more ventilation and natural lighting. The wings were changed from offices to classrooms. Eight new classrooms were added adjacent to the auditorium. The first floor has a significantly smaller balcony allowing a clear span across the main space. The upper floor has been removed.

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We can see the openness of the space and the natural light coming in from the sides. Also note the louvres at the top of the space creating more ventilation.

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Here is an exterior render of the redesigned space.

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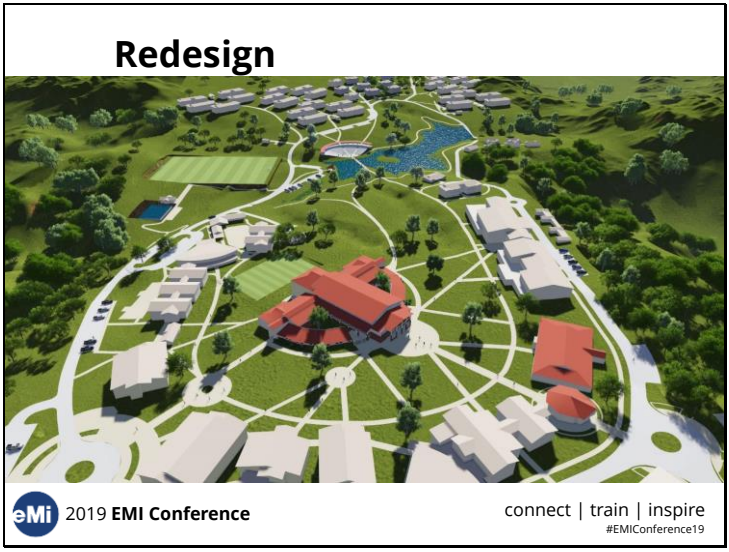

Here is a render of the community center within the context of the original master plan.
How do we move for the existing building to the redesign?

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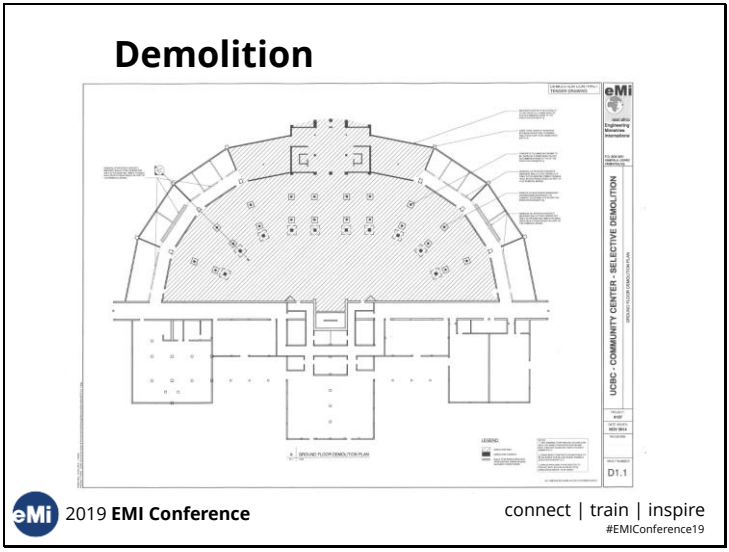

We start with demolition of the auditorium space. The hatched area is what was demolished, all the balcony structure and the main entrance.

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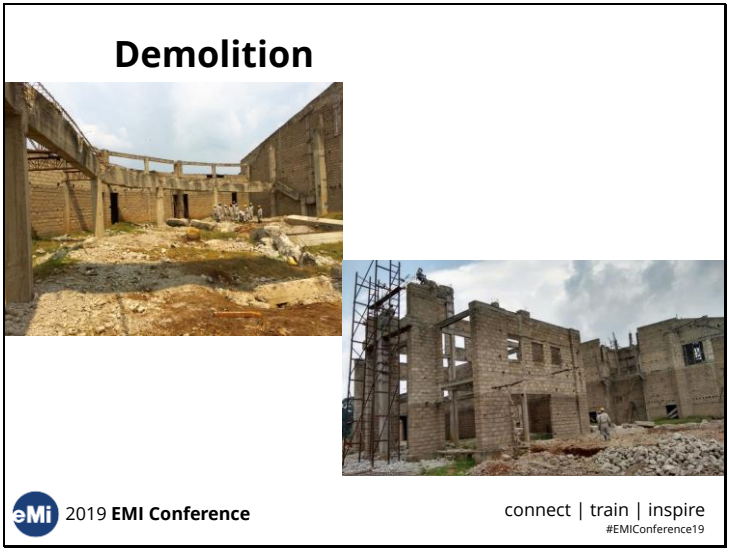

Here we see the removal of the balcony.

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Demolition

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Here we see progress on demolition of the front entrance

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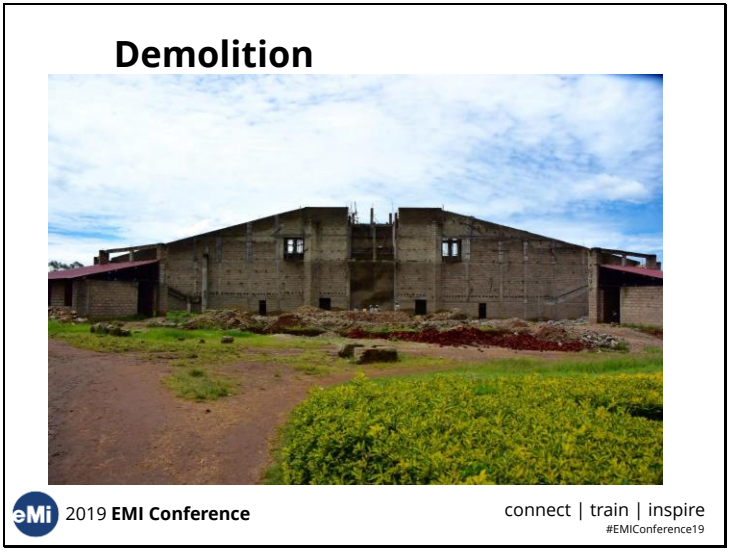

Here is the completed demolition of the auditorium.

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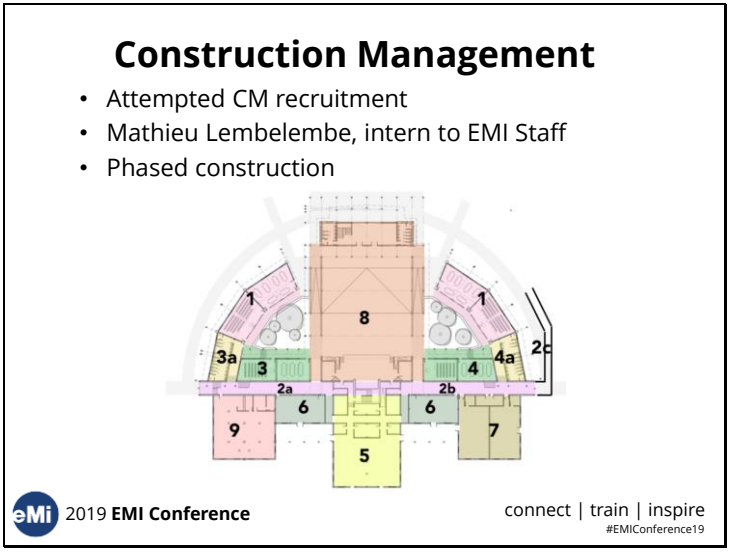

Adequate construction supervision was a requirement before restarting construction.
We attempted to recruit a construction manager through several vision trips, but nothing materialized due to the challenging location.

Then we had a Congolese intern who had studied architecture in Uganda, Mathieu Lembelembe. After he had completed 2 internships and was looking for work we presented the opportunity to go to Beni. He was hesitant at first, only committing to 3 months, hoping that something better would come up. The committed grew to 1 year and is now ongoing. He has capture the vision of the ministry to transform his country
Phasing was another consideration as we restarted construction. Here is the initial phasing plan, breaking it up into manageable sections for the contractor and oversight. This also allowed time for fundraising while making parts of the building useable now.

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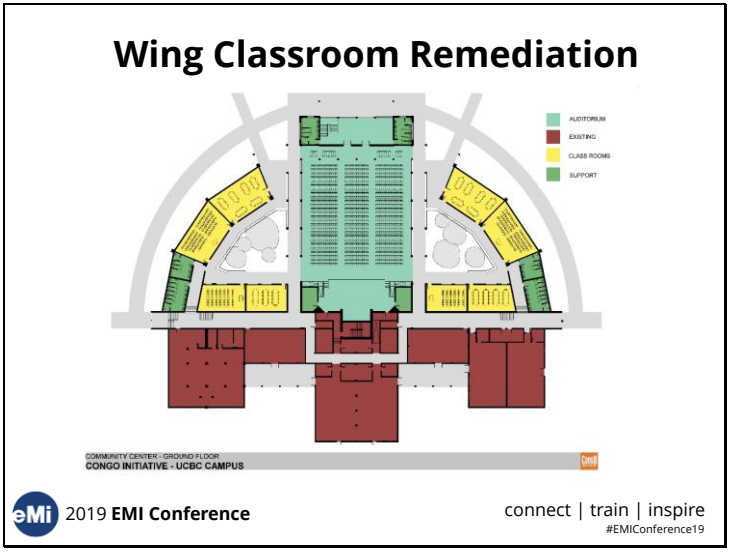

The first stage of construction was remediation of the wing adjacent to the auditorium, seen here in yellow.
We began here as this was the only single storey section of the building and it required the least work. It gave opportunity to evaluate the contractor and understand the constraints of the building in Beni.

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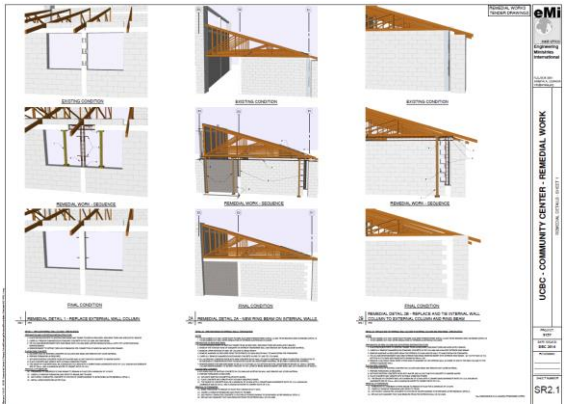
Wing Classroom Remediation



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Remediation involved repairing columns, reinforcing trusses and infilling walls to provide additional lateral support and to repurpose the space from offices to classrooms.

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Wing Classroom Remediation

Column and Beam Repairs

Here is some of the repairs

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And the finished renovations. The demolition was demoralizing, however the restart of construction brought renewed hope and excitement over the quality of the new construction.

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The next stage of repairing the community center was not the existing building, but a tent. As mentioned, the unfinished rooms were being used by the university as there is a shortage of space. To start working on the corridor and back of the building another space was needed for large gatherings meeting/chapel in the cafeteria.
While the auditorium could satisfy the need, at over $1 million, there were not enough funds. Instead an 800 seat tent was ordered from South Africa and installed at $100,000, ~30,000 being the tent.

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Here we see the site preparations, compaction, laying paving stones, and foundations for the tent.

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Here is the finished tent.

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Once the tent was erected, demolition could begin on the corridor. The height of the original corridor was 47’ with minimal connection between the two walls. We had concerns over the stability of the walls and poor quality masonry units.

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The walls we demolished down and new ring beam and connecting beams poured. Then the walls were built back up to roof level and room installed.

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We can see the finished corridor. This was an exciting accomplishment for the university as it was the first time that a roof was over the entire building.
We can see in this corner then next phase of construction, a 2 storey new addition with 4 classrooms.

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The new construction was smoother than remediation. We can see here pockets in the corridor wall to tie the floor beams to the corridor wall to provide support at a lower level.

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New 2 Storey Classrooms

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And here is the finished spaces. You can notice the staging of the corridor wall. This area is left unfinished until the auditorium construction.

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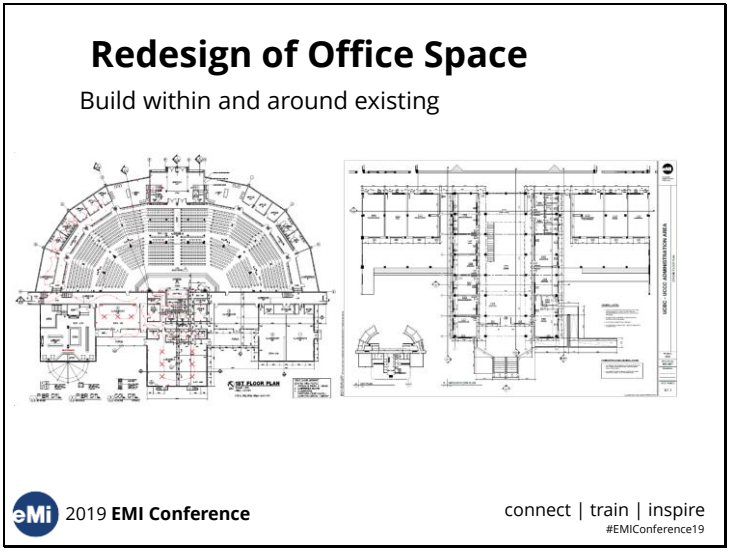

Just as the construction was being phased, the design was being phased as EMI was able and to stay ahead of construction.
As we began looking into the back of the building, we re-evaluated the needs of UCBC and CI at the time. The most pressing need was for office space. There was a desire to have the core of the organization in the community center building as it is the focal point of the campus.

As we considered the space, this is 60’ across. We introduced a atrium and clerestory to allow natural light and ventilation into the space. Offices in the center of the space would not be very comfortable.

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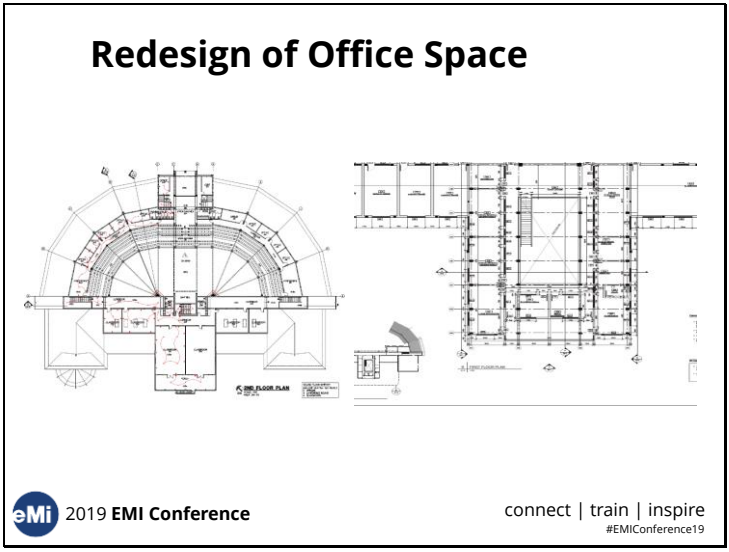

Here is the second floor plan. Since the money was yet to be raised, we designed flexibility into the wall locations so when construction begins we can adjust based on the current needs.

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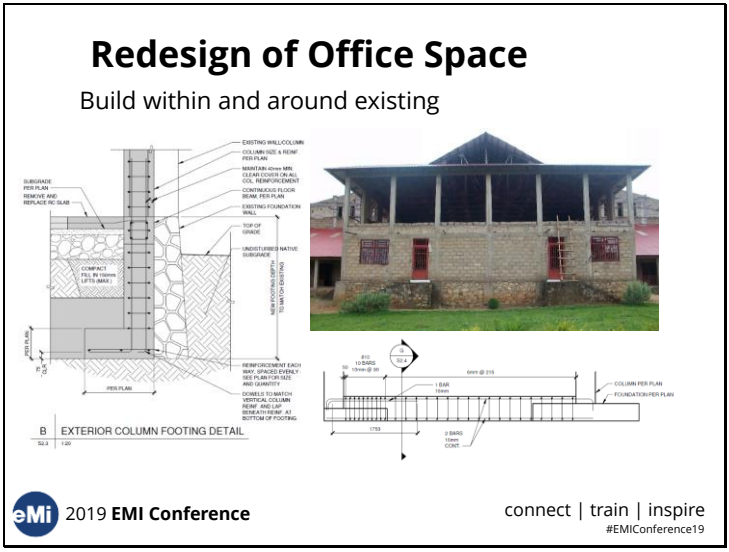

The structural assessment identified that 90% of the columns needed to be repaired or replaced. Again the philosophy was to keep what could be reasonably fixed and demolish what couldn't. We wanted to maintain the outside as much as possible, because the university was hoping that major demolitions were already done.
So we came up with a plan to build a new structure within the existing structure, connecting them where possible. The existing beams and columns were assumed to just be part of the wall.
The plan is to excavate within the building, strap beams connecting the exterior footings to the interior footings.

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Construction Challenges

-construction quality
-material availability
-political instability
-security – ongoing conflict
-Ebola

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We had challenged getting adequate and consistent concrete strength. Construction was put on hold twice due to insufficient strength. Months spent making test cubes, transporting them to Kampala (Car from Beni to border, transfer to another car to bring to EMI Uganda, then transported to testing lab.) The main issue was poor quality sand it had too many fines. The solution was to hand wash sand.

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Construction Challenges

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I will end with the challenge of transportation. Here is the bridge crossing the Semliki River, the main transportation route into Beni from Uganda. It was repaired but in the meantime trucks would meet on either side of the river and small boats would transport the materials across to the other truck.

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Local Context

- Why do we need to know?
- How do we learn?

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We have seen why we need to know the local context. But how do we learn? This is the reason EMI has local design professionals on our design teams and why we have planted field offices.