Designing a Sustainable Classroom Building in Thailand

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Abstract

The Doi Wiang Wittaya School in the rural Wawee community of Chiang Rai does not receive enough funding from the government to provide quality classroom buildings for its students. Poor physical infrastructure negatively impacts students' academic success (Young et al., 2003). The Sati Foundation aims to address this problem by providing the school with sustainable buildings using local resources to reduce construction costs. We interviewed the community, researched sustainable designs, consulted experts, and created an electronic design model to address the community's needs. We proposed a sustainable classroom building design and developed a comprehensive construction manual, to be used by the Sati Foundation and the Wawee community, which serves as a model for other schools in Thailand.

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Executive Summary

Students attending rural schools in Thailand tend to fall behind academically, compared to those attending schools in urban areas. One cause of this is that rural schools lack proper physical infrastructure. Studies have shown the positive correlation between the conditions of school buildings and the educational performance of students (Young et al., 2003). There are a number of factors that affect the conditions of school buildings including maintenance, temperature, air quality, lighting, and aesthetics (Young et al., 2003). In order to improve the conditions of rural schools and properly maintain them, the Thai government needs to increase its annual funds for these schools to match that of urban schools (World Bank Group, 2016). There is a need for sustainable, long lasting buildings in rural areas to make up for this lack of funding. Sustainability is defined as, “meeting the needs of the present without compromising the ability of future generations to meet their own needs,” (World Commission on Environment and Development, 1987). Our goal in this project was to design a sustainable classroom building for the students and teachers at the Doi Wiang Wittaya School in Chiang Rai. We considered the community’s wants and needs throughout our design process, along with the availability of local materials.

In order to do so, our project sought to accomplish the following objectives:

Objective 1: Identify community and building needs.

Objective 2: Examine existing sustainable school designs that incorporate local materials and address the community’s needs.

Objective 3: Introduce the preliminary design and construction methods to the community and sponsor for further evaluation.

Objective 4: Recommend a design that has the best use of sustainable materials and fits the needs of the community.

Methodology

To determine the scope of our project we identified the needs of the school community by visiting the Doi Wiang Wittaya School in the Wawee Community. For objective one, we interviewed the students, teachers, and village committee during our first visit. Many of the people we interviewed spoke their native language, therefore, their account was translated into Thai by other community members and was later translated into English. The team interviewed students in grades one through four using visual aids to make explanations and translations easier. We asked the students to draw two drawings; the first of their current school building, with features that they did not like drawn in red, and the second of their dream school. The drawings collected gave us some insight on what students wanted in a new school building. They also allowed us to discover aspects of the school that were in the most need of change. We found this by plotting the ocurrence of features students did not like. Students in grades five and six were interviewed in a group setting. We asked the students open-ended questions about the problems they have with the school’s infrastructure and improvements they would like to see. We also interviewed teachers because they are most knowledgeable about the school’s needs and optimal learning environments. We interviewed the village committee council to learn about their: involvement at the school; lifestyles, livelihoods, and cultural limitations; and their willingness to participate in the building process. All interviews were translated, transcribed, and analyzed by color coding recurring themes.

In addition to interviews, we also conducted physical observations for objective one. This was necessary to assess the physical quality of the buildings. Observations were rated on a scale ranking basis of 1 to 5. Observations were recorded by taking pictures to reduce bias and support ratings and written observations when analyzing data. For the building observations, we focused on lighting, temperature, aesthetics, and quality of maintenance.

To fulfill our second objective, we consulted various experts, including an architect and civil engineer, to help us create our design. After creating a 3D electronic model, we visited the Wawee community a second time to introduce our design and receive their feedback, completing our third objective. This allowed us to further improve our final design to fit the community's needs. The design plan and methods of construction were proposed to the community and a discussion was held to learn what concerns the community may or may not have. In this presentation of the design plan, the discussion held after the presentation allowed us to holistically use the community's concerns to create a revised, final design plan.

With the new design considerations, we were able to achieve our fourth and final objective. We created an improved design plan that not only incorporates the community's wants and needs, but also includes the use of sustainable materials. This final design will be included in the manual for the community and our sponsor, the Sati Foundation. The manual consists of the design plan as well as the construction methods that the community should follow in order to build their new classroom building.

Results and Recommendations

Community and Building Needs

Our findings during our first visit to the school allowed us to achieve our first objective, identify the community and building needs. We first decided to narrow our focus on to the third grade classroom building because it was in the worst physical condition. We discovered this through our interviews with the teachers and from our observations. In addition, the student drawings show frequent dislike of the windows and doors. Therefore, the major needs for this building were proper insulation and ventilation to protect the students from the cold in the winter and heat in the summer. In addition, we found several challenges within the community. Villagers had limited time to help with construction since their income depends on their everyday farming. Another challenge we discovered was the lack of experience the villagers have with large scale construction. These two challenges stress efficiency in the building process and the importance of providing comprehensive instructions of the building methods. The last major challenge we found was the community's preconceived notion about the use of natural materials. The team addressed this concern by incorporating both natural and man-made materials. Overall, to address the community's needs and the definition of sustainability, our design and construction requirements were insulation, ventilation, efficiency, ease of use, and cost-effectiveness.

Design

For the second objective, the team learned about various building methods and materials through previous studies and consultations with experts. This allowed us to correctly design the classroom building while also incorporating local materials and centralizing the community's needs. During the designing process, each aspect of the building was broken down and thoroughly assessed. First, a sturdy building starts with a strong foundation which is composed of layered rebar and poured concrete. As for the walls, local materials expert Mr.

Suppachai Posuwan introduced us to the ‘rammed earth’ building method, in which layers of earth are manually rammed into the shape of a wall. This lead us to the discovery of the compressed earth brick method. Both methods incorporate locally available soil, but the compressed earth brick method uses a manual, interlocking brick compressor that significantly reduces the manual labor and time required compared to rammed earth. This machine is a good investment for future construction. The bricks also have high thermal properties that address the insulation problem previously found.

Another major finding through the interview with the village committee was that a thatched roof is the most common roofing method in the area, however, we found through this interview that it only lasts two to three years and requires frequent repairs. After further research, we found corrugated metal decking to be the best choice for the roof since it lasts ten times as long as thatch roofs. A simple truss framework using steel was recommended by a senior civil engineering student at Chulalongkorn University, Mr. Chawin Thitichakorn (Mr. Win).

For ventilation, we researched different types of windows and doors. We considered the importance of natural lighting and ventilation in a learning environment and decided to put three large, transparent windows into the design as well as a weaved bamboo door.

We then combined these aspects to create our preliminary design. This design includes the considerations the team learned from consulting with the architect (Mr. Thana Uthaipatraku) and the civil engineer (Mr. Win). The community was pleased with the construction of the building and suggested their traditional method for closing the ventilation. Figure 1 shows the final design, which incorporates all aspects discussed, such as the walls, roof, door, and windows. The construction manual for our design can be found in Appendix A.

Figure 1: Final design incorporating the community’s needs.

In addition, based on the calculated labor requirements for the construction of the school classroom, we recommend for there be fifteen to twenty workers per day for this construction process, which would take approximately three months. Operation of the compressed earth brick machine needs about three to five workers per day and makes about three hundred bricks per machine per day. Operation time and manual labor needs can be determined based on the number of compressed earth brick machines the Sati Foundation can afford to purchase. It is also important to account for the skill of the community laborers because training on construction techniques would take more time than skilled laborers would. We recommend hiring professionals or finding voluntary professionals because it is beneficial for the proper training of unskilled community members. The community will be able to pursue new careers or continue to contribute to the improvement of their community with the new skills they will have. Concerns that we recommend our sponsor and the community to address in the future include, but are not limited to: updated technology, sanitary restrooms, and safe pathways.

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Notes:

Safe, Proud, Pam, and Jia all worked on all of the translation and transcribing of the interviews held while in the community.

Pam and Jia worked on writing our main deliverable of the construction manual, all in Thai.

Proud worked on the entire 3D model of our final design.

Chapter 1: Introduction

Education affects the intellectual life of most people and allows them to help advance society politically, economically, and socially (Asha Bhavan Centre, 2015). In countries with remote, rural areas, there is a connection between poverty and low quality education, as indicated by poor student performance and enrollment (Van der Berg, 2008). Quality education is hindered in rural communities because small schools are expensive to operate and properly maintain. There is a relationship between the physical state of school buildings and the academic performance of students (Duran-Narucki, 2008). Having a poor physical infrastructure undermines the cognitive stimulation students need to succeed (World Bank Group, 2015).

According to the World Bank Group, Thailand has insufficient quality schools in its rural areas (World Bank Group, 2015). The lack of rural schools in Thailand is caused by insufficient funding. The Thai government needs to increase its annual funding for rural schools by 4.8% to match that of urban schools. Due to this lack of funding, rural schools cannot properly maintain their buildings, ultimately influencing student performance (World Bank Group, 2016). One possible solution to make up for this lack of funding for a school's physical infrastructure is to introduce sustainable building methods in these rural areas. Sustainability is "meeting the needs of the present without compromising the ability of future generations to meet their own needs," (World Commission on Environment and Development, 1987). Satisfying the definition of sustainability includes the use of local materials and community involvement to design a building that is cost effective and long lasting.

Globally, organizations have been working to address the need for sustainable schools. For example, United World Schools has worked with communities in Ratanakiri, Cambodia incorporating the residents' input and labor into a design to construct schools using wood as their sustainable material (United World Schools, 2015). In Thailand, the Sati Foundation, our sponsor, is an organization that also addresses the need for sustainability. The Sati Foundation exists to enhance the life and education of underserved Thai youth.

Since farming is not lucrative and is the livelihood of the Wawee community in the hills of Chiang Rai, the students there are in need of sustainable classroom buildings. It is important to incorporate the community in the construction process to not only make the building sustainable but also the community, as they will be able to upkeep and maintain the physical infrastructure.

Our goal was to design a sustainable classroom building for the Doi Wiang Wittaya School in the Wawee community with the Sati Foundation. Our design was based on the community's wants and needs, construction challenges, and availability of local materials. In this project, our first objective was to identify the community and building needs. The second objective was to examine existing sustainable school designs that incorporate local materials and address the community's needs. The third objective was to introduce the preliminary design and construction methods to the community for further evaluation. The fourth and final objective was to recommend a design that incorporates the best use of sustainable materials and fits the needs of the community. The completion of these objectives enabled us to produce a final design of the classroom building for the Doi Wiang Wittaya School that can increase the quality of education for students at this school.

Chapter 2: Background

Our project focused on improving a classroom building at the Doi Wiang Wittaya School, and their need for sustainable classroom buildings. Figure 2 below shows the school, located in the Wawee district of Chiang Rai Province in northern Thailand.

Figure 2: Location of the project site.

This chapter provides background information on the different factors affecting student learning, education in rural Thailand, and our sponsor, the Sati Foundation. This chapter also discusses several methods of sustainable school design. We make the argument that there are positive and negative effects on student learning caused by the quality of the physical infrastructure of school buildings and classrooms.

2.1 Factors Affecting Quality of Education

There are many factors that affect a student's quality of education, including poor quality teachers, teaching materials, and physical infrastructure (World Bank Group, 2015). This project focuses on the physical condition of the students' learning environment. Studies have shown a positive correlation between the conditions of school buildings and the educational performance of students (Young et al., 2003). Factors that should be considered when assessing building conditions include maintenance, temperature, air quality, lighting, and aesthetics (Young et al., 2003). Studies show that the ideal temperature for students to learn in is between 68 and 74 degrees Fahrenheit (20 to 23 degrees Celsius). Temperatures outside of this range are linked to student discomfort and decreased attention spans (Schneider, 2002). Another factor that should be considered is poor air quality which has been overlooked in previous projects. Poor air quality affects approximately one in five students in America causing them to suffer from allergy-like symptoms, headaches, nausea, dizziness, and sleepiness (Schneider, 2002). Colors in the classroom have a strong psychological impact on students, persuading designers to use more pastel colors to increase productivity (Young et al., 2003).

In addition, the poor physical infrastructure of schools is often caused by insufficient funding (World Bank Group, 2016). The implementation of sustainable resources has been practiced all around the world which address the lack of funding (Gough, 2005). These practices are especially applicable to rural communities, such as those in Chiang Rai, due to the challenges they face by being so secluded. In order to improve the learning progress of students in the Chiang Rai community by incorporating these ideas, we must first have a better understanding of the community itself.

2.2 The Chiang Rai Community

In Thailand, education is provided by the Thai government's Ministry of Education. The government offers basic education to all of the students in the hill tribe communities. However, the quality of education in these areas is on average much lower than that in urban schools (Lathapipat, 2015). In the case of the Doi Wiang Wittaya School, the Thai government does not prioritize their funding because of the school's remote location. Therefore, the budget the school receives from the government each year is inadequate for meeting the school's needs.

In Chiang Rai, the history of migration to northern Thailand has also affected the quality of education that exists there today. Thai hill tribes living in the forests of northern Thailand are originally migrants from Burma, Laos, and China. Chiang Rai had an influx of people migrating from China, hailing from the Akha, Lahu, Haw, and Yao tribes, many speaking their own native language. These tribes are also in poverty due to the fact that their only income comes from farming (Thongdara et al., 2011). These hill tribes are amongst the most disadvantaged communities living in Thailand (Lee, 2014). Schools are still not a primary concern for these communities since villagers depend on farming to provide for their families. As such, many school buildings in Chiang Rai were not established until the late 1990's and were difficult to fund due to the existing poverty (World Bank Group, 2015).

2.3 The Sati Foundation

In order to provide a better quality education in rural schools, the physical infrastructure of the classroom buildings must be improved. The Sati Foundation has focused and identified a need for sustainable classroom buildings for the Doi Wiang Wittaya School. The mission statement as declared by the Sati Foundation is to mindfully serve the underserved and vulnerable youth of Thailand. The Sati Foundation focuses on education because it addresses multiple social problems, such as, reducing the number of runaway children. In past projects, the Sati Foundation has attempted to improve the health care and education of affected individuals by teaching them skills in the medical and science fields. They also collaborate with various organizations to create programs promoting awareness through art and other forms of expression. With the Sati Foundation's aid and passion for changing lives, designing a sustainable classroom contributes to their mission of serving the students of Thailand and to the educational development of the community as a whole (Rouypirom, 2003).

2.4 Sustainable Design

Sustainable development is defined as, "development that meets the needs of the present without compromising the ability of future generations to meet their own needs," (World Commission on Environment and Development, 1987). The definition of sustainability includes the use of local materials and community involvement to design a building that will last long enough to be used by many generations. Prioritizing sustainability in the classroom design is important because it will make our design environmental friendly, reduce the expenses for construction, and allow for the longevity of the building. The design plan will be beneficial for future generations since it can be used as a model for other hill tribe communities to replicate for their needs. With this, learning conditions for students can be improved for both now and in the future.

Sustainable Materials used for Rural Buildings

Sustainable building materials is an important aspect in building design. During its lifetime, the material must have low transportation costs, low toxic chemicals and emissions released into the environment, and low maintenance requirements in order to be considered as a sustainable material. The use of local materials satisfies the definition of sustainability because the cost of transportation and gas emissions are both reduced compared to materials transported from far away (Morton, 2013).

There are two types of local, sustainable materials: natural materials and reused/recycled materials. In many of the projects examined, the use of local lumber for building purposes was prevalent. For example, one study examined the use of bamboo because it is often readily available and grows quickly (Lekshmi and Subha, 2011). In addition, many civilizations use clay and mud to bind various materials to build walls and structures. An innovative recycled materials project was done in Chiang Mai, Thailand from a previous Worcester Polytechnic Institute Interactive Qualifying Project (IQP) project team. The team worked with the Greenroof^{TM} Company to design low carbon emission roofing tiles made of tetra paks (Bannish et. al, 2012). The advantages of these tetra pack roofs are that they are inexpensive, consist of recycled materials, and reduce building costs. For a material to be completely sustainable it must not create pollution during the manufacturing process and the usage period, it must also be in a continuous upcycling loop (McDonough & Braungart, 2013).

There are a number of factors that affect the ability to use local, sustainable materials. In Thailand, environmental restrictions of land and forest use affect the availability of natural resources. Approval from the Thai government is needed in order to use natural resources especially many types of trees. However, due to deforestation, the probability of approval is low (Leach, Mearns, Scoones, 1999). The use of materials becomes complicated because the cost of transportation of non-local materials to rural areas is extremely high (Lekshmi & Subha, 2011). Therefore, readily available local materials are the least expensive.

Community Involvement

Community involvement in the design process is an important aspect of this project. According to a study done on community building design processes in San José de Olaes, participation within a community is to, "be governed by the principles of equality, autonomy, public deliberation, respect for differences, monitoring by the public, solidarity, and interculturalism," (Enrique, 2016). We must consider all of these factors in order to properly involve the community while creating an effective design.

In a study done in Yunnan, China, researchers observed two different methods used in different communities involved in the planning and implementation of sustainability projects. In one village, a 'bottom-up' process was used, meaning the community was integrated into the innovation, planning, and development of new building and construction methods (Gao, 2016). This method allowed for the use of local knowledge and skills that integrated the communities' values and concerns and as a result, was well adapted within the community. Another method was a 'top-down' approach, meaning that the use of professional guidance from external forces was proposed to the village and its leaders (Gao, 2016). The use of external forces was valuable because professional guidance is needed in sustainable development. In conclusion, the study determined that the integration of both methods, rather than either one separately, could be beneficial to the overall success of a development project in many ways. This study showed that community development needs a balance between expert and community knowledge by means of interactions between villagers, leaders, and professionals. An important aspect of this method that can be applied to our project was realizing the villagers' self-reliance capabilities while also incorporating new knowledge and technology.

In the San José de Olaes study on community building design processes, this concept of community and professional involved design is labeled as "participatory design and construction" (Enrique, 2016). This study examined three different decision making and design processes in which designers involved the community: personal leadership, socialization, and participation (Enrique, 2016). The 'personal leadership' technique consisted of one community leader who was the head of the design process. In this case, the project was completed but had major design errors. 'Socialization' involved a technical team that proposed a design that the community then agreed on. The project involving 'socialization' was the most successful having been completed with no significant design errors. Finally, the 'participation' decision making process involved contributions from everyone in the community in both the design and building process. The project involving 'participation' was never completed and created conflict within the community. Therefore, complete community control of the project was not the most effective method of designing a community building, such as a school. The 'participation' decision making process was the most successful. According to this study, "it is said that it is important to have participatory processes so every voice in the community will be heard and everyone will see their work reflected on the infrastructure," (Enrique, 2016).

The positive outcomes of a community led sustainability project are that the community has control over the project and are empowered by their contributions. This will have beneficial impacts on the community in Chiang Rai as the members will be empowered to apply their skills and knowledge to enhance their livelihoods and the community as a whole. According to the evidence presented in the two studies, it is clear that participation from local communities in addition to guidance and leadership from outside experts and professionals, are necessary in designing a building. This ensures that the completion, effectiveness, and sustainability of the project are most successful. It is important to understand the techniques of incorporating the community to ensure that this project is being implemented effectively.

2.5 Conclusion

In this chapter, we argue that there is a relationship between physical infrastructure and learning progression. When a classroom is in a dilapidated state, the academic performance of the children is poor which leads to a poor quality of education. Such is the case in the Wawee community in which poverty greatly affects the standard in which classroom buildings are built, ultimately hindering the quality of education for all students. By working with the Sati Foundation, this project aimed to address the poor physical infrastructure by researching and examining different sustainable building design plans and methods that can be introduced to the Doi Wiang Wittaya School. In the next chapter, we discuss the methods of interviewing, observation, research, and design used to complete our objectives in this project.

Chapter 3: Methodology

The goal of our project was to design a sustainable classroom building for the Wawee community of Chiang Rai, Thailand. This design can be used as a model for future classrooms to be built in other village communities in Thailand. The following were our four objectives to achieve this goal:

Objective 1: Identify community and building needs.
Objective 2: Examine existing sustainable school designs that incorporate local materials and address the community's needs.
Objective 3: Introduce the preliminary design and construction methods to the community and sponsor for further evaluation.
Objective 4: Recommend a design that has the best use of sustainable materials and fits the needs of the community.

This chapter discusses our interview and observation methods used when we visited the Doi Wiang Wittaya School to achieve our first objective. For our second objective, we consulted with professional building experts to expand on our initial design. We narrowed our options to produce a preliminary 3D electronic design for the community to review, completing objective three. For objective four, we finalized our design which considered the community's suggestions and created a manual that explains construction and maintenance details.

3.1 Objective 1

The purpose of our first objective – identify community and building needs – was to develop an initial understanding of the context of the problems at the school in order to address them in our design. To identify these needs, we visited the Doi Wiang Wittaya School to interview the community members and collect data on the current conditions of the classroom buildings. The methods of human centered design, creating a design solution that specifically tailors to human needs, and community led sustainability were used to incorporate the perspectives and values of the community into the design. The information we wanted to learn from the community was: the community's needs regarding a new classroom building, the availability of local materials, and their willingness to participate in the building process. The community was interviewed using purposive sampling, which is selecting groups in a population that serve a specific purpose, since we focused on specific areas of the population (Sommer, 2006). All interviews were audio recorded to avoid any discrepancies during translation. In the case that the interviewees spoke a native language, their account was translated into Thai by other community members. All participants were informed of rights to confidentiality, which includes privacy and protection of information and any audio recordings.

We interviewed the students in grades one through four using visual aids to make explanations and translations easier. We asked the students to draw two drawings. The first drawing was of their current school building, with features of the school that students did not like were drawn in red. The second drawing was of their dream school, with features students wanted to see in a new school. Plotting recurrent features students did not like allowed us to discover aspects of the school that needed the most change. We then asked students the reasons behind what they drew, focusing on the features drawn in red. Students in grades five and six were interviewed in a group setting because they were older and could hold conversations in Thai. We asked them open-ended questions about the problems they have with the school's infrastructure as well as improvements they would like to see, since they have attended the school the longest. We interviewed teachers because they are most knowledgeable about the school's needs and optimal learning environment. We also interviewed the village committee council to learn about: their involvement at the school; their lifestyles, livelihoods, and cultural limitations; and their willingness to participate in the building process. All interview questions can be found in Appendix E.

Through convenience sampling within the community, we interviewed a local materials expert, Lieutenant Suppachai Posuwan, because he has experience with building his resort using local materials. We used an unstructured interviewing method to allow us to follow-up on previous interview questions and information that required further clarification. The interview recordings were translated and transcribed onto a table with 3 columns: line number, speaker, and audio; which included every detail and avoided summarization. The recordings were then analyzed by identifying recurring themes. We found that color coding our annotations was the most efficient way to analyze the data (Rabiee, 2004). A color code was created for each theme and supporting quotes were highlighted with the corresponding color.

In addition to interviews, we conducted physical observations to assess the quality of the buildings, mainly focusing on lighting, temperature, aesthetics, and quality of maintenance. Observations were recorded by taking pictures to: reduce bias, support ratings, and support written recordings when analyzing data. We used a scale ranking system of 1 to 5. Table 1 displays the developed criteria for each rating, from 1 being in the worst condition and 5 being in the best condition.

Table 1: Rating Rubric for Observations

1	2	3	4	5
Non-functional (does not perform what it's said to do). Feature poses physical harm. Negatively impacts learning.	Fairly functional (it is a temporary structure) - extent of damage is uncertain. Negatively impacts learning. Lasts less than 1 year.	Medium function Small flaws, that do not affect the function of building during that time but will get worse if left unfixed. It could stay 1-3 years.	The feature performs quite okay, and it could be improved. Would last up to 5 years. Little to no effect on learning.	Does not need improvements or is sufficient enough for 5-10 years. Sturdy and no physical harm posed. Beneficial to learning environment.

3.2 Objective 2

The purpose of our second objective – examine existing sustainable school designs that incorporate local materials and address the community's needs – was to create a preliminary design using local materials that addresses the needs identified in interview and observation analyses. We began by researching sustainable designs and sketched a layout of our design with detailed materials, including natural and man-made. To ensure that our design was substantial and safe, we consulted an architect and natural materials specialist, Mr. Thana Uthaipatrakul to discuss the use of natural materials in place of man-made materials. We also consulted with a civil engineer, Mr. Chawin Thitichakorn, to calculate and provide instructions for the foundation and framework of the building. In our research we conducted soil tests to evaluate the local natural materials (see Appendix N). After finalizing the design, we constructed a 3D electronic model of the building using the Rhinoceros 3D computer graphics software. This program was able to provide us with the exact number of bricks needed to build the classroom.

3.3 Objective 3

The purpose of our third objective – introduce the preliminary design and construction methods to the community and sponsor for further evaluation – was to involve the community by travelling back to Doi Wiang Wittaya School to present our preliminary design for feedback. We displayed our 3D design and provided 2D layouts to the audience which allowed them to easily understand our design. After explaining each aspect of the classroom, we held an open discussion for questions and concerns. We also presented to the Sati Foundation to ensure that our design met their requirements.

3.4 Objective 4

The purpose of our fourth objective – recommend a design that has the best use of sustainable materials and fits the needs of the community – was to incorporate the community's feedback and needs to provide them with our final design, which consisted of the final building design, the construction manual, and the final cost analysis. The construction manual provided detailed instructions for our sponsor and the community about each feature of the building. It also includes the amount of materials needed for each feature; this was calculated based on the specific material and specific function of the feature. In addition to specifications on the amount of materials we needed for the building, we also provided a cost analysis. This was obtained by visiting the closest construction supplier to the school in the Wawee community, to record the prices of building components providing the most accurate cost analysis to our sponsor. For the materials that were not provided at the construction supplier we conducted further research to produce a complete cost analysis.

Chapter 4: Results

This chapter discusses key findings on the needs of the classroom building, the needs of the community, and findings for different aspects of our design. We first identify building and community needs through the analysis of our interviews and observations. We then discuss findings regarding different aspects of our design adopted through consultations with building experts and research studies. We also discuss findings from the presentation of our final design to the community to ultimately present the development of our final design.

4.1 Findings Regarding Building Needs

We found that the Doi Wiang Wittaya School is in need of new classroom buildings. To achieve part of objective one, understanding the needs of the buildings, the team interviewed the village committee and found that everyone in the village wanted their children to attend a good school. In our observations of the school buildings, it was noted on our rating sheet that most of the classrooms received poor rankings in cleanliness and maintenance. The classroom buildings for grades one, two, and three were marked with the lowest rankings and notes from our observations. For example, all three buildings received a score of 1 (posing physical harm) for cracks and flaws. In order to understand the community and building needs, we also interviewed the teachers. Through these interviews we found that the first, second, and third grade classrooms are called ‘can buildings’ and have been used for more than ten years with the initial intention of being temporary. In an interview with architect Mr. Thana, we learned that the tin roofs of the ‘can buildings’ are contaminated with asbestos, a cancer-causing agent. As a result, the overall physical infrastructure of the school is very poor. Evident between observations and interviews, the biggest need within the community was improving the classroom buildings. This observation is supported by the higher scores the bathrooms, walkways, and recreational spaces received in our rankings. New classroom buildings will contribute to the village members’ desire for their children to attend a good school that guarantees their safety.

Furthermore, all teachers agreed that the worst of the three ‘can building’ classrooms was the third grade classroom. The third grade classroom had the most issues ranging from leaks in the roof to a broken door. Figure 3 shows that the third grade classroom was made of a metal framework with 1-cm thick plastered sheets inserted as walls. The walls were peeling, breaking, and exposing the outside. The metal framework was rusting, which over time will affect the structural integrity of the building posing danger to anyone inside it. The paint was peeling and could potentially be toxic, as we do not know what it was composed of. A big green fabric cloth covered most of the empty window space barely keeping out the weather. We learned from our observations that the third grade classroom was in fact in the worst condition, supporting the teachers’ opinions. As a result, we decided to design a new third grade classroom building for our project.

Figure 3: Conditions inside third grade classroom. The photo on the left shows the deterioration of the walls and the photo on the right shows the chain-linked windows.

Our field research on the school building conditions revealed that a major problem with the physical infrastructure of the school was its lack of protection from the natural environment and weather conditions. To further complete objective one – identifying the building needs – we had students highlight disliked features of their school in red. Figure 4 shows a bar graph of the recurrence of disliked features.

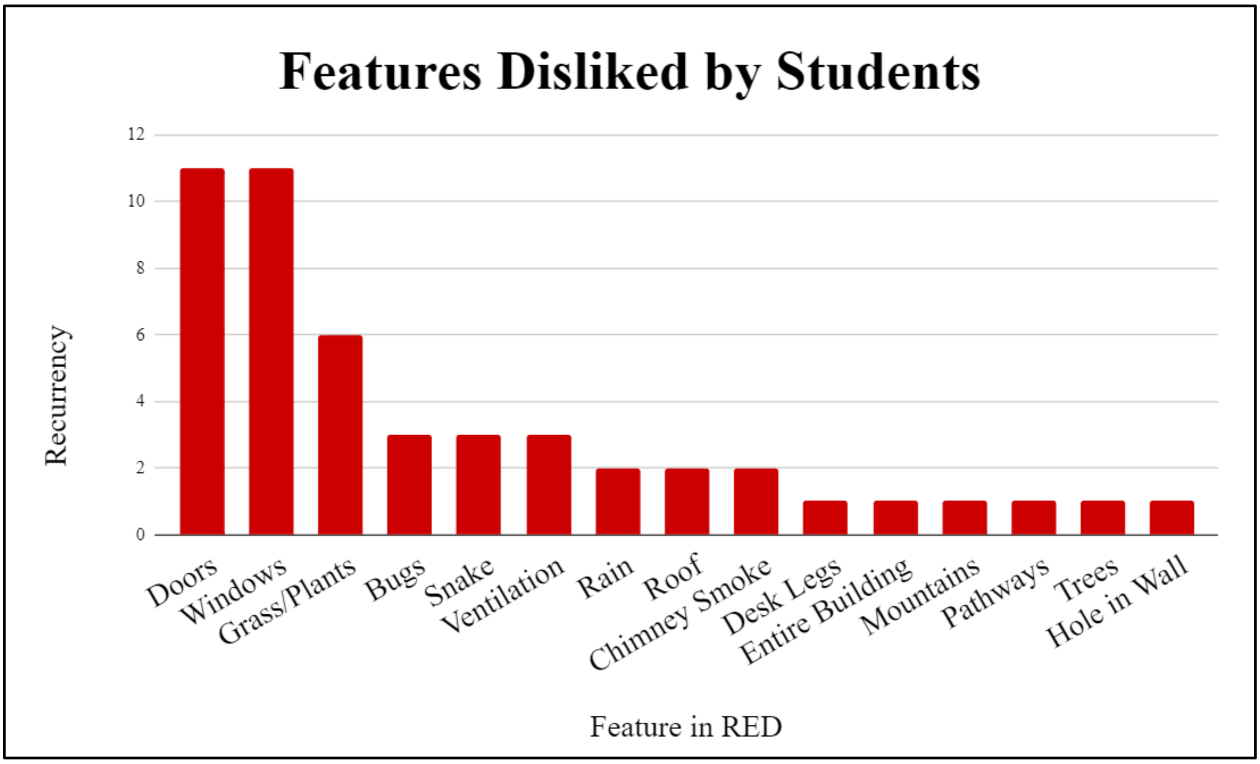

Figure 4: Bar graph of features students did not like in 1-4 student drawings.

Openings to the outside, including doors, windows, ventilation, and a hole in the wall make up more than half of the disliked features. The majority of dislike for windows and doors come from the third grade drawings. Additional commonly disliked features included interference from the natural environment and weather, like plants, insects, animals, and rain. This was evident by our observations of the exposed openings from the windows, doors, and ventilation. Through our interviews with the fifth and sixth grade students, we learned about additional problems concerning the windows. Windows either had no opening and closing mechanism or they were not transparent. Thus, the teachers would leave the windows open, regardless of the outside temperature and weather, to let in natural light. Therefore, the students were too cold in the winter or too hot in the summer. In addition, during our visit to the school we observed that stray dogs walk in and out of the open classrooms throughout the day which were distracting for students.

We also learned from the interview with the community council that students were heard by their parents complaining about the cold temperature in their classrooms. In interviews with the older students, they complained about both discomfort from the cold in the winter and poor air flow from the ineffective fan in the warmer months. One of the teachers, Ms. Am, expressed a desire for a new fan or ventilation system. We observed that the third grade classroom’s thin walls have poor thermal properties for keeping the temperature regulated within the room. Thus, the room is too cold in the winter, too hot in the summer, and lacks protection from the natural environment outside. We observed that the upper ventilation in the classroom did not have a closing mechanism, therefore contributing to the problem of unregulated classroom temperatures. The windows and doors also lacked versatility along with the ventilation which is another reason for these irregular temperatures. Windows, doors, and ventilation need to be versatile enough to function properly in both the summer and winter months. Reliable windows and doors are necessary to solve the problem of animals, bugs, and weather entering the classroom as well. Therefore, a focus of our design was on providing the students and teachers with a thermally efficient building through proper insulation and ventilation. This became the main focus of our design because ambient classroom temperatures significantly impact student performance and attention (Young et al., 2003). In addition, outside distractions like weather and nature take away a student’s valuable time for learning, ultimately affecting their quality of education.

Our design focused on the third grade classroom building and the goals for our design still apply. We had to design the classroom so that it: protects from the outside and unpleasant nature, regulates temperature properly, includes proper ventilation, and incorporates proper lighting.

4.2 Findings Regarding Community Needs and Opinions

We also interviewed the teachers and village committee to understand the community’s needs and opinions which completed objective one. Our methods revealed that the community had preconceived notions about the use of natural materials. For example, through our interviews, we learned that both teachers and villagers were quite skeptical about the use of natural materials. Initially, the teachers expressed in their interviews that they thought natural materials were expensive. Additionally, problems that the village committee experienced with natural materials included: lack of strength, difficulty of treatment, and short material life. For example, the village committee expressed that they did not like clay because using it requires skills, specific tools, and time. They said that when they tried to build with clay and mud it did not work as they expected. When asked about bamboo, the village committee said that bamboo was prone to insect infestation. Although bamboo walls provide better airflow, the committee stated that they do not last as long as cement. Our interviews revealed that some of the community members currently use natural building materials, like bamboo, for their homes but their general attitude was that they are more difficult to use than modern materials. In addition, the village committee commented that natural materials were not as aesthetically pleasing compared to modern materials. Therefore, community members prefer cement and other modern building materials over natural materials.

Our interviews revealed that the community was skeptical of using natural materials. They have more trust in modern construction, however, the goal of our project was to provide them with a sustainable school building using local materials. Thus, a design challenge was developed to satisfy expectations of modern buildings, aesthetics, and use of local materials. Part of this challenge included first understanding this social stigma and then overcoming it by introducing new ways of using the local materials. Therefore, we suggested that our new classroom design be a hybrid of natural materials and modern materials so that it is sustainable with a modern appearance.

Our interview with the village committee also revealed that the village members are willing to participate in the construction of the new classroom building. Village members thought that there was nothing wrong with the school's physical infrastructure, however they said if improvements were necessary then they would still be willing to participate in the construction. Through the interview, we learned that most of the villagers are farmers and rely on daily salaries. The community council said that the villagers cannot be present at the construction of the classroom building at all times because they cannot afford to be absent from their work frequently. Being absent from work means that they will not earn any income for the day to support themselves and their family. One of the village committee members even suggested working in shifts so that the workload can be distributed evenly within the community. Although community participation in the project was available, it was limited. This presented the challenge of developing a construction design that was efficient and easily understandable.

An additional finding we learned through the interviews with the village committee and teachers was that the villagers were not experienced with large scale construction. The director of the Doi Wiang Wittaya School, Mr. Sahud Promkudkaew, said in the interview with the teachers that we have to provide the villagers with information and knowledge about qualitative and quantitative information, such as the ratio of mixing clay and cement. He said that proper instructions were necessary in order for them to participate in the construction of the school. When asked about their experience in construction, the community council replied that they only how to build on a small scale using only wood. They also said they do not know where to find less expensive construction materials. Village members learned most of their construction techniques from past experiences in building their own homes and acknowledged their lack of skill and expertise. A concern among the villagers was that the methods that they had learned from their past experiences were not the correct or most efficient. Further lack of construction knowledge was displayed in the villagers' dislike for and knowledge of natural materials. In the interview with the local materials expert, Mr. Suppachai Posuwan said, "the villagers don't know how to make those local materials to be sustainable," but villagers said they would be willing to learn if provided with proper instruction and tools.

Since village members' skill set is very limited, instruction and demonstration of building techniques will be a challenge for the construction of the school building. This is challenging because it increases the detail of instructions needed and the labor time. We created a manual that is easy to understand and can be used as a reference during the construction process.

Workshops and programs for the community must be held for thorough understanding of the building details. The Sati Foundation said they would be willing to gather a team of construction volunteers which could potentially decrease this challenge.

Based on our findings about the needs and social considerations of the community, our main design goals and criteria were specified and defined more clearly. Additional findings revealed that the community's limitations included: availability of labor and workforce, limited construction skills, and stigma towards the use of local materials. These will ultimately contribute to the design of the most efficient and comfortable learning environment for the students. We have created our design plan based on these goals and limitations through further research and consultation.

Although our methods revealed the needs of the physical infrastructure of the classroom, they also uncovered findings that could not be properly addressed in the scope of this project. The first problem the teachers addressed when asked about possible improvements to the school was for updated technology, which included internet and computers. The fifth grade students remarked that they desired a computer in their classroom because the only one they had access to was the one computer in the sixth grade classroom. They said their favorite thing to do on the computer was look up science experiment videos which helps them learn. Since proper technology, along with proper infrastructure, is important for education, these problems should be addressed in the future to further improve the quality of learning (Higgins, 2012).

4.3 Findings Regarding the Design

This section discusses aspects we considered in creating our design through consulting with building experts and researching several studies. The major component of the design was the wall building method. We will discuss multiple building methods for the wall using soil, a readily available natural material. Later sections will discuss design aspects including the foundation, roof, and windows. The community's needs and opinions were centralized as we arrived to each design decision.

Wall

The three different wall building methods described in this section are: compressed earth, rammed earth, and adobe brick. Figure 5 depicts these methods and further explanations will be provided for each method.

Figure 5: From left to right: compressed earth machine and bricks (Henry Industrial Co., Ltd., 2015), rammed earth method (the Akaa project, 2015), and adobe method with formwork (CLC, 2011).

Compressed Earth

In order to achieve objective two – researching and developing a sustainable school design that incorporates local materials and addresses the community's needs – we identified local materials near the Doi Wiang Wittaya School. We observed that there was a lot of soil and clay that was readily available. An important finding was that the compressed earth brick method can use this local soil. We came to this decision by researching various methods that use the local soil and clay. The method of making compressed earth bricks requires the use of a manual machine to compress soil and cement into interlocking-shaped bricks. A soil and cement mixture is placed into the machine's mold, compacted together, and left to dry. This brick machine is easy to use and not very time consuming; compressing the earth brick is done very quickly and the bricks only require two to three days to dry. The compressed earth bricks address the building's need for increased thermal efficiency.

Rammed Earth

Through our interview with local resort owner Mr. Suppachai, we were introduced to a method called rammed earth. Rammed earth is a combination of clay and cement that is rammed until it is very dense. This method is typically used to build walls using a mixture of cement and fine soil that does not contain larger rocks. This mixture is then put into a temporary formwork and then rammed down until it is about half of its original volume. We learned from consulting with architect Mr. Thana that rammed earth also lasts a long time, which contributes to our goal of making the classroom building sustainable. We also learned from this interview that the main downside of rammed earth was that it is labor intensive and time consuming. Therefore, rammed earth would conflict with the challenge of the community's limited time commitment. This process might also be too complicated to introduce to the community in a building manual because it requires a large complicated formwork and rigorous manual ramming of the soil until it is compact (Rammed Earth, 2018).

Adobe Brick

Another method introduced to us through our interview with Mr. Thana, was the adobe brick method. The adobe method is another version of rammed earth that also uses a soil and cement mixture but instead of forming one solid wall, this method forms solid bricks. A wooden formwork that has several rectangles is used to form the bricks. Once the soil-cement mixture is compressed, the formwork is lifted to reveal the adobe compressed bricks. The traditional brick layering method is used to form the walls, in which mortar is created using a watered-down version of the soil-cement mixture and placed in between the bricks. This method also has a lot of positive thermal properties and multiple bricks are created at the same time, however, limitations to this method are that it is time consuming and labor intensive.

Chosen Method

All three of these methods were considered because they reduced the cost and transportation of cement, and they use natural local materials. We examined each method, considering the pros and cons to make our final decision. Table 2 displays the features of what is most important in our design: cost, labor, time, and thermal benefits, that apply to each of these methods.

Table 2: Comparison of Wall Methods

	Features			
Method	Cost	Labor	Time	Thermal Benefits
Compressed Bricks	✗	✓	✓	✓
Rammed Earth	✓	✗	✗	✓
Adobe Bricks	✓	✗	✗	✓

Out of the three building methods, compressed earth bricks, rammed earth, and adobe bricks, we decided that the compressed earth brick method was the best option, taking the community's desires into consideration. We realized that the machine required to make the interlocking-shaped compressed earth bricks was expensive, costing between $1000 and $1390 (33,000 baht and 45,870 baht) per machine, but the machine is an investment (Dwell Earth, 2016). The Doi Wiang Wittaya School and the Sati Foundation can use it to build many more school buildings making our design easily reproducible, which will save expenses for cement. The machines are simple to use and still produce bricks with the same thermal qualities as the rammed earth method and adobe method.

The soil used for compressed earth bricks must be tested for sand, clay, and silt composition. Soil for compressed earth brick production requires about 70% sand and 30% silt and clay (Ndume Limited, 2010). We collected soil samples from three different potential 'borrow pits,' areas in which the community would obtain the soil for construction, near the school in Chiang Rai. All three soil samples were tested for composition of gravel, sand, silt, and clay, using the Sedimentation Test. The soil collected was topsoil which typically contains organic matter. Results show that this soil is currently not suitable for compressed earth brick production because the clay content is too high. The Sedimentation test conducted (see Appendix N) revealed that all three samples collected contained 0% to 15% sand and gravel and 85% to 100% clay and silt accordingly. However, the possibility of using soil with high clay content is still realistic since there are other zones of soil as you dig deeper into the earth. These layers typically start to contain more sand deeper within the soil (Adam, 2001). The community must dig into the ground to the sandier soil levels below and test the soil composition again. If the soil test continues to reveal high levels of clay, sand can be bought as an additive to reach the 70% sand ratio need for compressed earth bricks.

Although only steel rods are commonly inserted in the holes of a brick (refer to Figure 5) to stabilize the building, we decided to use both steel rods and bamboo to allow for a more affordable design plan. In the interview with Mr. Suppachai, we found that there were no environmental restrictions to using bamboo as they grow quickly and are readily available. The only concern with the use of bamboo is that it must be over four years of age because young bamboo is susceptible to moth infestation (*pyrausta aurata*). These moths feed on the sap within young bamboo, however this problem can be avoided as long as older bamboo is used. To reduce the cost of steel rods and address sustainability, we decided to use steel rods only in areas of the building where support is most needed: corners and middle of the walls. Bamboo will be inserted for the remaining brick holes. This compromise between natural and man-made materials allows us to address both our goal of sustainability and the community's preconceived notion of natural materials.

Foundation

A concrete and steel rebar foundation was the most effective foundation for the school. Through our research and consultation, we learned that the structural integrity of the building depends on the strength of the foundation. Foundations made with natural materials had insufficient strength to support the building. Therefore, the modern constructed concrete and steel reinforced foundation is the most effective solution.

Roof

For the framework and truss calculations, we consulted senior civil engineering student at Chulalongkorn University, Mr. Chawin. Using the dimensions of the classroom we provided, Mr. Chawin was able to calculate all necessary measurements to ensure that our building was safe and can support all the components of the roof. As for the roof, itself, there were many options to choose from, but we decided to use corrugated metal decking. The first option we considered was a thatched roof, which is the layering of vegetation. Thatched roofs make use of the leaves and natural materials in the area, making the roof inexpensive. The community members also have thatched roofs for their homes that they constructed, therefore, they know how to make them and we would not have to give them detailed instructions. Some major challenges to this method were that the thatched roofs do not last long (only about two to three years) and they need frequent repairs since they can easily leak. Natural material specialist, Mr. Thana, suggested one way to make a thatched roof last longer was to increase the steepness of the roof so the water can run off quicker. The problem with making the roof steeper is that it would require more skills and materials because it complicates the trusses used. He also suggested that we use a metal roof underneath so the thatch part does not need to be fixed or replaced. This makes the roof last seven to nine years. However, we want our design to be as low maintenance as possible because villagers stressed that they have limited time. Therefore, thatch roofs add time, labor, and complications in the design. With all of these downsides, we decided a thatched roof would not be suitable for the community and sustainability aspect of our project.

Through our research we found that there are many types of metal roofs commonly referred to as corrugated metal roof, which means, "shaped into a series of parallel ridges and grooves so as to give added rigidity and strength," (Oxford Dictionary, 2018). Metal roofs can last between twenty to fifty years, but their composition is important. The school's current metal roofs are thin and trap in the heat making the classrooms hot in the summer and extremely loud when it rains. There are many ways to address these problems. The problem of temperature can be improved using a heat reflective coat and adding a layer of aluminum sheet under the metal roof to act as a radiant barrier. Research on cool roofs show that white is the "coolest" color to coat roofs as it has the highest solar reflectance (SR), defined as, "the fraction of sunlight (0 to 1, or 0% to 100%) that is reflected from a surface," (GCCA & R20, 2012). However, since white can get dirty easily, many companies offer a variety of colored roofs that are highly reflective with the same SR as a white coated roof and double that of an uncoated roof. To address sound issues a layer of polyurethane (PU) foam can be added underneath to absorb noise. During our second field visit we discovered that the local construction supplier offers different colored roofs that are entirely composed of three layers:

a heat reflective coat, metal, and PU foam. Fortunately, all these components address the building needs on insulation of temperature and noise and address the community's needs in efficiency as they do not have to install multiple layers. Table 3 summarizes the comparison between thatched roof and layered roof. As shown, even though the layered metal roof requires additional expense, it has all the features we were looking for.

Table 3: Comparison Between Thatch and Layered Metal Roof

	Features					
Roof Method	Time	Labor	Cost	Age	Thermal Benefits	Noise
Layered Metal	✔	✔	✘	✔	✔	✔
Thatch	✘	✘	✔	✘	✔	✔

Windows

Transparent windows allow for natural lighting which contributes to the learning environment and can help reduce the cost of electricity over time. The windows observed in the third grade classroom were exposed metal chain-linked fencing. They provided lots of natural lighting but did not provide protection from the weather. Therefore, the new windows should be transparent and able to be closed when needed. Glass and clear plastic were the only options in this case, as Mr.Thana stated there were no natural materials that would fit the needs for transparent and closed windows.

Another important technique we found through Mr. Thana was that there would be no air flow if windows were built on only one side of the building. Since the third grade classroom building had only one big open space on one side of the wall, our design has windows built on opposite sides of the building to allow for air flow. Further research studies show that the most effective method of ventilation is when windows are placed directly opposite to each other, also called cross-ventilation (Jiang & Chen, 2002). Hence, we will be putting windows on the opposite walls.

Cost Analysis

After considering all of our design aspects, we created a cost analysis. The total cost of the sustainable classroom building is approximately 267,000 baht. This includes the cost of materials, transportation, and labor. We calculated the cost of materials and transportation by visiting the local construction supplier in the Wawee community to obtain accurate prices and rates for each aspect of our design. We calculated the cost of labor through research of the average daily wage for construction workers in Thailand. Table 4 below displays the total cost of our design, excluding demolition costs. The cost of the classroom building is compared to the average cost of construction of a single-story building in Thailand in 2014 (Pornchokchai, 2014). Our design cost is significantly less than a single-story building of the same size. If all workers are volunteers, then the cost is further reduced.

Table 4: Cost Analysis

Building Type	Minimum Cost	Maximum Cost
Single Story Building	548,XXX baht	715,XXX baht
Sustainable Classroom	~267,XXX baht	
Excluding Volunteer Labor	~195,XXX baht	

4.4 Findings Regarding Community Feedback

The second visit to the Wawee community was to accomplish objective three of our project plan. The team introduced the design plan and construction methods for the classroom building to the community. The team presented the specific aspects of the design plan with visual aids including a 3D model using a computer program. The computerized model allowed the community leaders to clearly see and interact with the model, making our explanations and translations easier to understand. After all details of the proposed design plan were presented, we held a discussion with the community about the design model. We learned that the community was pleased with our design, but there were some concerns. The first concern was about the compressed earth brick machine. The community members questioned if they can keep the machine, but that is a decision for our sponsor to make. The second concern was whether or not all of the community members would approve the design. We anticipated that the community as a whole would want to discuss the design plan to voice their opinions and concerns as well as raise any questions that they may have.

We asked the community members what aspects of the design and construction method they wanted to see altered or replaced. The community suggested using a traditional ventilation flap that is already familiar to them. A method familiar to the community would be better used than a new method because it does not require training and consequently reduces construction time. The design is a simple bending mechanism that will allow the flap to open during the summer and close in the winter. The flap itself is made by sewing dried bamboo grass. We incorporated this additional consideration into our design. This enabled our project to be enhanced in the community's best interest. The final design recommendation was in the form of a design manual and included the best use of sustainable materials, encompassing the needs of the community. The next chapter discusses the final recommendations of the design of the classroom building.

Chapter 5: Recommendations

The goal of our project was to design a sustainable classroom building for the students and teachers at the Doi Wiang Wittaya School in Chiang Rai. To accomplish this goal, we used several methods as previously discussed to gather data. An analysis of our findings suggested that the major needs of the school were improving the insulation and ventilation. We developed an effective design that addresses the problems with the current school and concerns of the community. In this chapter, we offer recommendations on the different construction methods and materials used for the sustainable classroom. We describe what we have learned and highlight the implications for future work in which the community members can further improve the classroom buildings within the school. We also provide suggestions for the Sati Foundation for how they can use the recommended methods as a model for other schools.

5.1 Building Recommendations

This section describes each aspect of our building and construction recommendations.

Wall Building Material and Method

We recommend using the compressed earth brick method for the walls of the new classroom building. We found that compressed earth uses a mixture of soil and cement and the compressor can have different molds to create several desired shapes. We propose the use of interlocking bricks that can easily stack on top of each other since they reduce labor and time when compared to traditional brick layering. In order for there to be enough bricks for the whole building, we recommend that approximately two thousand bricks be made. This number was found through the computer design program we used to create our 3D model. Figure 6 below shows a compressed earth brick machine along with the different shaped bricks it can produce. A manual machine must be purchased to produce these earth bricks. This is a large expense but is an investment for the community because the villagers will be able to construct other buildings using this method.

Figure 6: Compressed Earth Brick Machine. Compressor above and different compressed earth brick shapes below. (Linyi Fulang Trading Co., Ltd., 2014).

In addition, having a clay brick wall will increase the thermal efficiency of the room and act as a natural sound barrier. This addresses our key finding that the current classrooms at the school do not provide proper protection from natural elements, such as the cold and heat, which is necessary for a productive and ideal learning environment (Young et. al, 2003). The use of readily available soil in the Wawee community reduces the cost of transportation of construction materials, making it an effective natural and local material. To reinforce the walls, steel rods are typically inserted into about every three to four holes and then concrete is poured into the holes. However, bamboo can replace the steel rods without compromising the structural stability of the building. We recommend this method as another way of incorporating natural, local materials to reduce expenses.

Soil for compressed earth brick production requires about 70% sand and 30% silt and clay (Ndume Limited, 2010). Soil samples that were collected and tested contained 0% to 15% sand and gravel. Although the soil collected was topsoil and deeper soil layers typically contain more sand, we recommended that the community dig deeper into the 'borrow pits' and test the soil again. If proper soil levels are not achieved, then sand must be purchased as an additive to the soil to achieve the proper composition.

Doors and Windows

Since our project focused on sustainability, we recommend for the community to handmake a door using the available bamboo which would decrease the cost of buying a premade door. This technique flattens the bamboo and frames it. A wood filler is also recommended to seal any openings. This secures the door, preventing animals (such as dogs, insects, and snakes) or the weather from getting into the building, and addresses the students' disliked features, as shown in Appendix D.

Ample natural lighting is important for productivity within a workspace (Young et. al, 2003). Therefore, we decided to include three large windows in the classroom building. The windows will be glass for transparency and will open and close to allow for airflow. Across the top of the classroom will be an opening to allow for more ventilation when it gets hot in the summer. This will not have a glass pane but can be covered using the community's traditional method of a flap composed of weaved bamboo grass. The community's traditional method is recommended as opposed to newer methods because the community is already familiar with this type of construction. The flap will open during the summer to generate airflow and be closed in the winter to keep the heat in (see Appendix A). A screen will also be installed to ensure that the building is completely enclosed, when desired.

Roofing Material

In order to further address the needs of the classroom building as described by the students and teachers, we recommend using a layered corrugated metal roof and steel trusses. A metal roof will last much longer and does not require as much labor as a thatched roof or any other natural roofing material does. These two aspects are important since the community explained that they can only contribute limited time to help with construction and since our goal was to make the building sustainable. We recommend a metal roof that has a heat reflective coat to reduce the temperature. We also recommend that the metal also contains a thick PU foam layer of insulation to reduce outside noise.

Foundation

We recommend using the common concrete and rebar method for the foundation because it is the most stable construction method. The rebar will be laid out in four layers, the first layer is horizontal, then the next layer vertical, and so on to form a grid pattern. Concrete is then poured over the rebar to create the foundation floor. No other method of building or use of natural materials for the foundation proved to be sufficient for the stability and strength this building needed. Based on the dimensions of the school our building design requires one hundred twenty steel rebars in order for the building to be properly supported. The foundation, posts, and lentils, which support the bricks above the windows and door, require forty-four bags of concrete. We calculated these amounts by separating the function of each of the features, for example the foundation was calculated on its own. We calculated the number of cement bags needed based on the volume of the foundation. The same procedure was carried out for the six posts and four lentils. We recommend buying these materials, including the window and roofing materials at the local construction store to ensure lower transportation costs. Figure 7 below is the 3D model of our final design.

Figure 7: 3D Model of final design.

Size and Aesthetic

Since a larger classroom will allow for more versatility in the layout of the furniture, we recommend increasing the layout of the classroom building from 5 m x 8 m to approximately 5.75 m x 8.30 m. In the future, the community could use the compressed earth brick machines to attach the first and second grade classrooms to the third grade classroom. In terms of the interior and aesthetics, the school can involve the students in the painting of the walls. We recommend the use of light, pastel colors since these colors were shown to increase student productivity (Young et. al, 2003).

5.2 Community Recommendations

For the laborers, we split up each aspect of the building, since a different number of people will be needed for different parts. Based on the calculated labor requirements for the construction of the school classroom, we recommend for there be fifteen to twenty workers per day for this construction process, which would take approximately three months, if volunteers are available at least two days a week. We recommend that approximately five of these workers be professional construction workers to facilitate the entire building process and the rest of the workers to be community volunteers. The operation of the compressed earth brick machine requires three to five workers per day in order to make about three hundred bricks per machine. Operation time and manual labor needs can be determined based on the number of compressed earth brick machines the Sati Foundation can afford to purchase.

It is also important to make a note of the skills the community laborers have because training on construction techniques takes more time than that of skilled laborers. We recommend hiring or finding voluntary professionals for the proper training of unskilled community members. Incorporating the community in the building process will allow villagers to be able to maintain and repair the building themselves without having to pay for these services from outside organizations. This is imperative, as it also provides the community with a new skill set that they could use to pursue new jobs.

5.3 Recommendations to Our Sponsor

We recommend that the Sati Foundation hire a professional team for the removal of the asbestos in roof. Asbestos is extremely hazardous during any construction project and would cause harm to any trained individual involved in the removal process. Although this can significantly increase the demolition cost of the building, it is necessary for the safety of all involved.

The Doi Wiang Wittaya School faces needs that are very specific to their school and the physical infrastructure of their classroom buildings. We found that the physical infrastructure of individual classroom buildings on the campus differed from one another. Our school design could be used as a model for other schools, but the model should be an adaptation of our design to match the specific needs of the given community. In accordance to the school's needs, adjustments can be made with further research and analysis. Modifications to the original design are possible in the future due to age of materials, safety concerns, and unpredicted building challenges.

In addition, we recommend further investigation into the school classroom needs beyond the building construction. Much of the feedback received from the students and teachers highlighted needs that could not be properly addressed in this project. For example, both the students and teachers mentioned the need for updated technology, including computers and the internet. The effectiveness of the students' education in their classroom can only be addressed to a limited extent with the classroom design. Therefore, to effectively provide quality education to students in hill tribe schools, all of these problems need to be addressed.

Chapter 6: Conclusion

The Ministry of Education in Thailand provides funding for public schools around the country. Unfortunately, schools in rural areas lack sufficient funding to properly maintain their buildings ultimately affecting student performance (World Bank Group, 2016). The Sati Foundation needed a sustainable classroom building for the Doi Wiang Wittaya School in Chiang Rai, Thailand, using local materials to reduce transportation costs. We used human-centered design techniques to address the community's and school's specific needs and challenges in our school design. Our design requirements were determined through interviews and observations. Our design needed to address: insulation and ventilation, efficiency of construction process, and incorporation of both natural and manmade materials. Our final design addresses these requirements since the materials of the metal roof both keep the room at comfortable temperatures and reduce outdoor noise. The walls consist of bricks made using the compressed earth brick method which have a high thermal mass. The weaved bamboo door with wood fillers stops drafts from entering the classroom. The foundation satisfies the villagers' want in having modern materials that they're comfortable using, also providing a strong foundation to erect the building. The windows allow for lots of natural lighting while still protecting students from the outside weather. Finally, the ventilation made of bamboo will allow heat to escape the room and will be covered when it's cold out. All of these aspects will positively contribute to the learning environment for the students at Doi Wiang Wittaya School.

Though we focused on one building, many aspects of the school need to be addressed. The school wishes that they could have upgraded technology in the classroom, a creative space, safe pathways with railings, and more sanitary restrooms with western toilets instead of squatting toilets. Because these needs are beyond the scope of our project and time, we will inform our sponsor so more projects can be created to serve the the needs of the school. Most importantly, our project was able to address the needs of the third grade classroom building. The school can use the same method to build new first and second grade classroom buildings as well. This project minimized the cost of a new school building while also incorporating the community's needs. Due to all of these considerations, we were able to improve the Doi Wiang Wittaya School's physical infrastructure, therefore their quality of education.

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Appendices

Appendix A: Construction Manual

คู่มือ

สำหรับการก่อสร้างอาคารเดี่ยวหนึ่งชั้น
จากวัสดุท้องถิ่น เพื่อความมั่นคงและยั่งยืน

(กุมภาพันธ์ พ.ศ. 2561)

คณะวิทยาศาสตร์ จุฬาลงกรณ์มหาวิทยาลัย และ
คณะวิศวกรรมศาสตร์ Worcester Polytechnic Institute

ร่วมกับ มูลนิธิสติ

คำนำ

คู่มือฉบับนี้เป็นส่วนหนึ่งของวิชา 2302307 INTERACTIVE SCIENCE AND SOCIAL PROJECTS ระดับปริญญาตรีปีที่ 3 จุฬาลงกรณ์มหาวิทยาลัย และ Worcester Polytechnic Institute โดยมีจุดประสงค์ ที่จะได้ศึกษาหาความรู้จากการทำงานร่วมกับมูลนิธิสติ ซึ่งรายงานนี้มีเนื้อหาเกี่ยวกับความสัมพันธ์ทางด้านสังคม ความรู้เกี่ยวกับการก่อสร้าง และการพัฒนาชีวิตความเป็นอยู่ของชาวบ้านในต่างจังหวัด การทำงานร่วมกับชาวต่างชาติเพื่อแลกเปลี่ยนความคิดทางด้านคุณภาพความเป็นอยู่ของชาวบ้านในประเทศไทยและต่างประเทศที่มีความแตกต่างกัน ตลอดจนการประยุกต์ใช้ ตามศัพท์ที่ว่า "Sustainability" หรือ "ความพอเพียงและยั่งยืน" แสดงให้เห็นถึงการดำรงค์ชีวิตด้วยต้นเองและพึ่งพาอาศัยทรัพยากรรอบข้างในการนำมาประยุกต์ใช้เพื่ออนาคตที่ยั่งยืน

ผู้จัดทำได้เลือกหัวข้อโครงงานนี้ เนื่องมาจากเป็นเรื่องที่น่าสนใจ รวมถึงเป็นการส่งเสริมการใช้ชีวิตอย่างพอเพียงและยั่งยืนเพื่อให้ชาวบ้านได้นำไปประยุกต์ใช้ด้วยตนเองและสืบต่อไป ผู้จัดทำต้องขอขอบคุณ Professor Dr. Supawan Tantayanon, Aj. Steven Taylor, Aj. Esther Boucher, Lieutenant Suppachi Posuwan, Mr. Chawin Thitichakorn, นายธนา อุทัยภัตรากูร, พลตำรวจเอกศุภชัย โพธิ์สุวรรณ และทุกคนที่ให้ความช่วยเหลือและให้ความรู้ มาโดยตลอด ผู้จัดทำหวังว่าคู่มือฉบับนี้จะให้ความรู้และเป็นประโยชน์แก่ผู้อ่านทุกๆ ท่าน

ฉัตรพล ลิขิตขจร
นัชชา รุ่งภักดีสวัสดิ์
วีราวัลย์ มโนเกษมสันต์
สิริภัทรา จันทรานุวัฒน์
Maddie Brennan
Josue Canales
McKenna Dunn
Lyra Huynh

สารบัญ

สถานที่

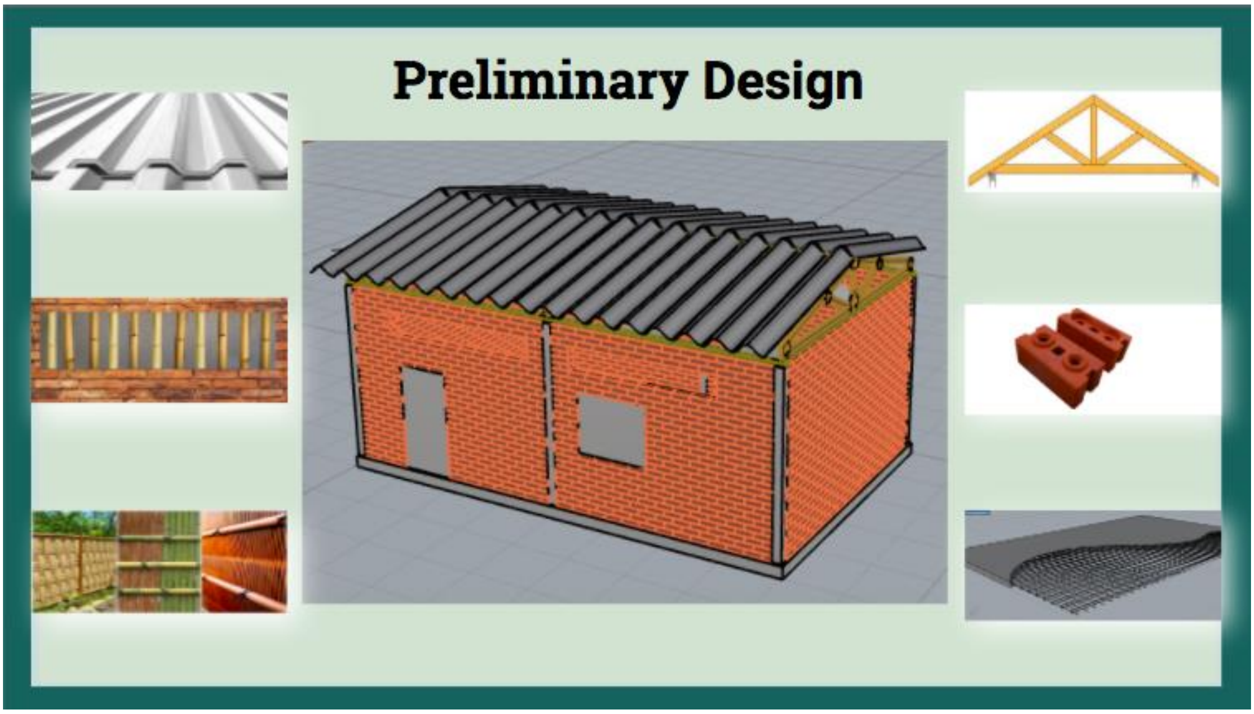
โรงเรียนดอยเวียงวิทยา ที่อยู่ หมู่ที่ 19 บ้านจู้จี้ ตำบลวาวี อำเภอแม่สรวย จังหวัดเชียงราย 57180
ได้ก่อตั้งเมื่อวันที่ 3 พฤศจิกายน พ.ศ. 2539
เป็นโรงเรียนเครือข่ายพัฒนาคุณภาพการศึกษาโรงเรียนบ้านวาวี และเป็นองค์กรปกครองส่วนท้องถิ่นวาวี
ทางโรงเรียนเปิดการสอนตั้งแต่ชั้นอนุบาลปีที่ 1 ถึง ระดับชั้นประถมศึกษาปีที่ 6 ณ ปัจจุบัน
ทางโรงเรียนดอยเวียงวิทยาอยู่ภายใต้การบริหารระบบของผู้อำนวยการ นายสหัส พรหมขัติแก้ว
จำนวนนักเรียนทั้งหมด 98 คน และคุณครูบรรจุทั้งหมด 8 ท่าน บริเวณภายในโรงเรียน
มีอาคารสร้างเสร็จทั้งหมด 8 อาคาร ซึ่ง 3 ใน 8
อาคารเป็นอาคารชั่วคราวที่มีมาตั้งแต่วันที่โรงเรียนดอยเวียงวิทยาถูกก่อตั้ง

ดังนั้น จากการสำรวจบริเวณรอบข้างและอาคารเรียน
อาคารที่ได้ถูกเลือกเป็นแม่แบบในการทำโครงงานนี้ คืออาคารประถมศึกษาชั้นปีที่ 3
โดยมีจุดประสงค์เพื่อพัฒนาชีวิตความเป็นอยู่ของนักเรียนของโรงเรียนดอยเวียงวิทยา

รูปภาพที่ 1 . อาคารเรียนชั้นประถมศึกษาปีที่ 3

ข้อมูลวัตถุดิบ

- รากฐาน
  - เหล็กเส้น
  - ปูนซีเมนต์
  - ทราย
  - ไม้แบบ
  - หินทราย(หินโม่)
- ผนัง
  - เครื่องอัดอิฐบล็อกประสาน (พลาสติกใสหรือน้ำยาเคลือบเหล็ก)
  - ดิน
  - เสาปูนสำเร็จรูป
  - ปูนซีเมนต์
  - แล็กเกอร์
- ประตู
  - บานพับ
  - น็อต
  - วงกบ และ ไม้แบบ
  - บานประตูท่อนไผ่สาน
- หน้าต่าง
  - วงกบ
  - หน้าต่างสำเร็จรูป
  - ตระปูขึง
  - ไม้แบบ
- ช่องระบายอากาศ
  - มุ้งลวด และ ลำต้นไผ่
  - บานพับหน้าต่าง
  - ไม้ล็อครูปตัวแอล
- หลังคา
  - เหล็กกล่องไม้ขีด
  - น้ำยากันสนิม
  - พียูโฟมเมทัลชีท
- เสาหลัก, คานทับหลัง, คานเอ็น, เสาเอ็น
  - เหล็กเส้นข้ออ้อย
  - เหล็กเส้นกลม
  - คอนกรีต
  - ไม้แบบ



รูปภาพที่ 2 ส่วนประกอบต่างๆ

คอนกรีต

ขั้นตอนการเตรียมคอนกรีต

1. คำนวณปริมาณซีเมนต์ ทราย หินโม่(หินทราย) น้ำ และค่ายุบตัว ตามสูตรดังนี้

ตัวอย่าง *ปริมาตรสิ่งก่อสร้าง 1 ลูกบาศก์เมตร*

สัดส่วนของคอนกรีต คือ ***ซีเมนต์ : ทราย : หินโม่ = 1:2:4***

รูปภาพที่ 3 สัดส่วนการผสมปูนซีเมนต์

หน่วยน้ำหนักของปูนซีเมนต์ = 1,400 กก./ลบ.ม.

หน่วยน้ำหนักของหินทราย = 1,450 กก./ลบ.ม.

วัตถุดิบ	**น้ำหนัก(กก.ต่อ ลูกบาศก์เมตร)**	
	ซีเมนต์พอร์ตแลนด์ (คอนกรีต)	**ซีเมนต์ ตราเสือ(ฉาบ) 40 กก./ถุง**

	50 กก./ถุง	ครั้งที่1	ครั้งที่ 2
ซีเมนต์	305	1953.125	1953.125
ทราย	635	4882.8125	5859.375
หินทราย	1275	-	-
น้ำ	185	9-12 ลิตร	9-12 ลิตร

ตารางข้อมูลแสดงตัวอย่างการคำนวณปริมาณปูนซีเมนต์

<u>ค่ายุบตัว</u> = 10 ซม./ลูกบาศก์เมตร

**การคำนวณนี้ขึ้นอยู่กับชนิดของซีเมนต์ จากการคำนวณน้ำหนักตามที่กำหนดข้างต้น*

2. อุปกรณ์ในการผสมซีเมนต์

อุปกรณ์	รูปภาพ	วัตถุประสงค์
1. ไม้บรรทัดปาดปูน		ฉาบปูนในพื้นที่กว้างๆ โดยใช้ในการทำระดับให้เรียบเสมอกัน
2. ถังเพลผสมปูน		ผสมปูนให้เข้ากับวัตถุดิบอื่นๆ
3. จอบและพลั่ว		ใช้ขุดดินและผสมคลุกเคล้าส่วนผสม

4. เกรียงเหล็ก เกรียงไม้ เกรียงเหล็กขัดมัน	  	เกรียงเหล็ก มีทั้งชนิดสามเหลี่ยมและสี่เหลี่ยม สำหรับชนิดสามเหลี่ยม ใช้ในงานก่ออิฐ ชนิดสี่เหลี่ยมใช้สำหรับขัดมันและใช้ตีเส้นปูนขัดมัน หรือตกแต่งผิวปูนฉาบในขั้นสุดท้าย เกรียงไม้ ใช้สำหรับตกแต่งหรือกดปูนให้เรียบ เกรียงเหล็กขัดมัน ใช้สำหรับขัดมันผิวปูน
5. ถังน้ำหรือถังใส่ปูน		ใช้สำหรับใส่ปูนที่ผสมแล้ว นอกจากนั้นยังใช้หิ้วปูนและตัวส่วนผสมอีกด้วย
6. คีมผูกเหล็ก		ใช้สำหรับตัดลวดหรือผูกเหล็กให้แข็งแรงก่อนที่จะเทปูน
7. เหล็กสกัด		ใช้สำหรับตอกกะเทาะปูนหรือรอยแตกร้าวในงานปูนออกทิ้งไป เพื่อทำการซ่อมแซมแก้ไข

8. ค้อนปอนด์ และค้อนไม้ ค้อนปอนด์หรือคอนพะเนิน		เป็นค้อนที่มีน้ำหนักมาก ทนแรงกระแทรกสูงใช้ตีเหล็กขนาดใหญ่มีหัวหลายชนิดหลายขนาน คือ หัวสองหน้า หัวตรง หัวขวาง ค้อนไม้เป็นเครื่องมือใช้สำหรับ เคาะ ตอก ทุบ ตี ชิ้นงานหรือเครื่องมือบางชนิด เพื่อรักษาสภาพพื้นผิวของชิ้นงานหรือเครื่องมือไว้ มีทั้งกลมและหัวเหลี่ยม
9. ระดับน้ำ		ใช้จับระดับในการก่ออิฐในแนวนอน
10. ไม้เมตรหรือตลับเมตร		ใช้วัดขนาดหรือระยะต่างๆ

อุปกรณ์เสริมต่างๆสำหรับงานช่าง ได้แก่

11. ฟองน้ำ

12. ปุ้งกี๋ ใช้ใส่หรือตวง หิน ทราย ในการผสมปูน ทำด้วยพลาสติก

13. ลูกดิ่ง ใช้สำหรับหาระดับในแนวดิ่ง เพราะการก่ออิฐต้องได้ดิ่ง ได้ระดับ

14. กระบะไม้ถือปูน ส่วนมากกระบะไม้ถือปูนใช้ใส่ปูนก่อและปูนถือ โดยตักจากถังใส่ปูนอีกทีหนึ่ง นอกจากนั้นใช้กระบะกลับปูนมาที่จะก่อหรือถือปูน

15. แปรงดอกหญ้า ใช้ในงานหินขัด หินล้าง หรือในการฉาบปูน

16. ตะแกรงร่อน ใช้ร่อนทรายและปูนขาวที่สกปรกหรือปนกากออก (เปลือกหอย เศษหิน ดิน อื่นๆ)

17. ฉากเหล็ก ใช้จัดมุมต่างๆ ในการก่ออิฐให้ได้ฉาก

18. ด้าย ใช้สำหรับทำระดับในการก่ออิฐและถือปูนให้ได้ระดับเสมอกัน

19. ดินสอ ใช้ขีดทำเครื่องหมาย

20. แปรงสลัดน้ำ ใช่ชุบน้ำแล้วสลัดใส่บริเวณที่ต้องการจะฉาบปูน เพื่อให้พื้นมีความชุ่มชื้น

21. ชอล์คเส้นหรือเต้าดีด ใช้สำหรับตีเส้น ให้ได้ระดับก่อนที่จะทาสี หรือฉาบปูน

22. ประแจดัดเหล็ก มีลักษณะเป็นเหล็กตันมีร่องตรงปลายทั้ง 2 ข้าง ใช้สำหรับดัดเหล็กให้โค้งงอตามลักษณะที่ต้องการ

3. ขั้นตอนการผสมคอนกรีต (สำหรับโรงเรียนดอยเวียงวิทยา)

3.1 คำนวณน้ำหนักวัตถุดิบ

3.1.1 ฐานราก

a. ปริมาตร = 8.3 เมตร X 5.75 เมตร X 0.15 เมตร = 7.15875 m^3

วัตถุดิบ	**น้ำหนัก (กก./ม^3)**	**ปริมาตร (ม^3)**	**น้ำหนัก(กก.)**
ปูน	305	7.159	2183.419
ทราย	635	7.159	4545.806
หินทราย / หินโม่	1275	7.159	9127.406

- ปูนพอร์ตแลนด์ จำนวน 44 ถุง
- น้ำประปา = 660 ลิตร
- ค่ายุบตัว = 71.58 ซม.

3.1.2 เสาหลัก (6ต้น)

b. ปริมาตร = 0.15 เมตร X 0.15 เมตร X 3.5 เมตร = 0.07875 m^3

วัตถุดิบ	**น้ำหนัก (กก./ม^3)**	**ปริมาตร (ม^3)**	**น้ำหนัก(กก./ต้น)**	**น้ำหนักรวม(กก.)**
ปูน	305	0.0788	24.019	144.114
ทราย	635	0.0788	50.038	300.228
หินทราย / หินโม่	1275	0.0788	100.47	602.82

- ปูนพอร์ตแลนด์ จำนวนทั้งหมด 3 ถุง
- น้ำประปา = 45 ลิตร
- ค่ายุบตัว = 4.725 ซม.

3.1.3 ทับหลังด้านบน (8 ท่อน)

c. ปริมาตร = 0.10 เมตร X 0.15 เมตร X 3.9 เมตร = 0.0585m^3

วัตถุดิบ	**น้ำหนัก (กก./$ม^3$)**	**ปริมาตร ($ม^3$)**	**น้ำหนัก(กก./ท่อน)**	**น้ำหนักรวม(กก.)**
ปูน	305	0.0585	17.843	142.744
ทราย	635	0.0585	37.148	297.184
หินทราย / หินโม่	1275	0.0585	74.588	596.704

- **ปูนพอร์ตแลนด์ จำนวนทั้งหมด 3 ถุง**
- **น้ำประปา** = 45 ลิตร
- **ค่ายุบตัว** = 4.68 ซม.

3.1.4 เสาเอ็น (8 ท่อน)

d. ปริมาตร = 0.075 เมตร X 0.15 เมตร X 3.0 เมตร = 0.03375 m^3

วัตถุดิบ	**น้ำหนัก (กก./$ม^3$)**	**ปริมาตร ($ม^3$)**	**น้ำหนัก(กก./ท่อ น)**	**น้ำหนักรวม(กก.)**
ปูน	305	0.0338	10.309	82.472
ทราย	635	0.0338	21.463	171.704
หินทราย / หินโม่	1275	0.0338	43.095	344.76

- ปูนพอร์ตแลนด์ จำนวนทั้งหมด 2 ถุง
- น้ำประปา = 30 ลิตร
- ค่ายุบตัว = 2.704 ซม.

3.1.5 ทับหลังใต้หน้าต่าง (3 คาน)

e. ปริมาตร =0.10 เมตร X 0.15 เมตร X 4.5 เมตร = 0.0675 m^3

วัตถุดิบ	น้ำหนัก (กก./$ม^3$)	ปริมาตร ($ม^3$)	น้ำหนักรวม(กก.)
ปูน	305	0.0675	20.588
ทราย	635	0.0675	42.863
หินทราย / หินโม่	1275	0.0675	86.063

- ปูนพอร์ตแลนด์ จำนวนทั้งหมด 1 ถุง
- น้ำประปา = 15 ลิตร
- ค่ายุบตัว = 0.675 ซม.

3.1.6 อเสของหลังคา (บนกำแพง)

f. ปริมาตร = ปริมาตรรอบนอก - ปริมาตรรอบใน

= (0.10เมตร X 8.25 เมตร X 5.7 เมตร) - (0.10เมตร X 7.95 เมตร X 5.4)

= 0.4095 m^3

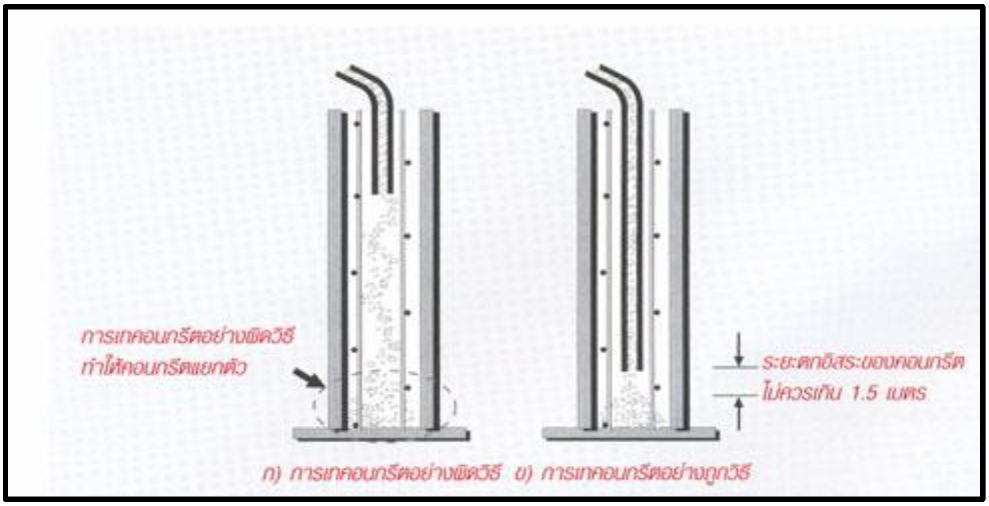
วัตถุดิบ	น้ำหนัก (กก./$ม^3$)	ปริมาตร ($ม^3$)	น้ำหนักรวม(กก.)
ปูน	305	0.4095	124.898
ทราย	635	0.4095	260.033
หินทราย / หินโม่	1275	0.4095	522.113

- ปูนพอร์ตแลนด์ จำนวนทั้งหมด 3 ถุง
- น้ำประปา = 45 ลิตร
- ค่ายุบตัว = 4.095 ซม.

3.2. นำวัตถุดิบที่ตวงเรียบร้อยตามปริมาตรของสิ่งก่อสร้างในส่วนนั้นๆ ในแต่ละส่วนมาผสมให้เข้ากันจนเป็นเนื้อละเอียด เพื่อป้องกันฟองอากาศขณะใช้คอนกรีต การผสมควรทำต่อเมื่อต้องการก่อสร้างสิ่งนั้นเท่านั้น เพราะคอนกรีตไม่ควรผสมล่วงหน้าเป็นเวลานาน

ขั้นตอนการเทคอนกรีต

1. การเทคอนกรีตแบบหล่อ ในแนวดิ่ง
   ระยะที่อิสระหรือระยะจากปากภาชนะถึงพื้นไม่ควรห่างเกิน1.5 เมตร (รูปภาพที่3)



รูปภาพที่4 วิธีการเทคอนกรีตที่ถูกวิธี

2. สังเกตุอัตราการอัดแน่นของคอนกรีตให้เหมาะสม อัตราการเทไม่ควรเร็วเกินไปหรือช้าเกินไป
3. วัดระดับชั้นที่เทไม่ควรเกินครั้งละ 45 เซนติเมตร
4. ทำการอัดแน่นในแต่ละชั้น มีหลายวิธีดังนี้
   a. '*ใช้มือ*' เหมาะสำหรับการเทคอนกรีตสดที่ค่อนข้างเหลว ในปริมาณที่น้อย อัดแน่นโดยการใช้อุปกรณ์ตำหรือกระทุ้งบริเวณรอบ ๆ เหล็กเสริมและสิ่งที่จะฝังติดในคอนกรีต
   b. '*เครื่องเขย่าคอนกรีตชนิดติดข้างแบบ*' นิยมใช้ในงานคอนกรีตอัดแรงหรือโครงสร้างขนาดบาง
5. สังเกตุการเรียงตัวของเนื้อคอนกรีตไม่ให้มีช่องว่างหรือรอยแยกระหว่างชั้นการเท ถ้าตรวจพบการไล่ของน้ำขึ้นมาบนผิวคอนกรีตชั้นที่เทก่อน <u>ควรหยุดเทและกำจัดน้ำที่ไล่ออกให้หมด</u> ก่อนที่จะเทคอนกรีตชั้นถัดไป

ข้อควรระวัง : ไม่ควรเทคอนกรีตกระทบกับแบบหล่อเหล็กเสริม หรือสิ่งที่จะฝังติดในคอนกรีต เพราะอาจทำให้คอนกรีตแยกตัวได้

ขั้นตอนการบ่มคอนกรีต

เพื่อรักษาระดับปริมาณความชื้นและอุณหภูมิของคอนกรีต โดยเฉพาะในช่วงอายุเริ่มต้นของคอนกรีตให้อยู่ในสภาพที่เหมาะสม เพื่อลดการแตกร้าวของคอนกรีต และทำให้คอนกรีตมีกำลังและความคงทนสูง

'การบ่มในแบบหล่อ' แบบหล่อไม้ที่เปียก และแบบหล่อเหล็ก สามารถป้องกันการสูญเสียความชื้นได้ดี วิธีนี้จัดได้ว่าง่ายที่สุด เพียงแค่ทิ้งแบบหล่อให้อยู่กับคอนกรีตที่หล่อไว้ให้นานที่สุดเท่าที่จะทำได้ และคอยดูแลให้ผิวด้านบนคอนกรีตมีน้ำอยู่ โดยน้ำนั้นสามารถไหลซึมลงมาระหว่างแบบหล่อกับคอนกรีตได้

ฐานราก

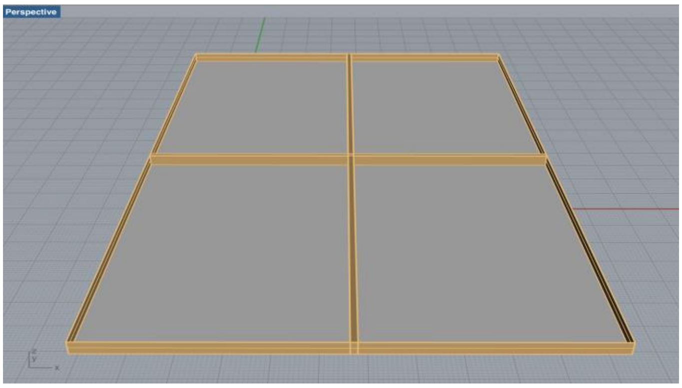
1. ขั้นแรกคือการเตรียมพื้นที่ ในการปรับระดับพื้นที่อาจจะต้องมีการถมที่ดินเพื่อปรับระดับให้เหมาะสม เวลาที่เหมาะสมที่สุดในการถมที่ดินคือช่วงหน้าแล้ง (ช่วงเดือนธันวาคม - เดือนพฤษภาคม) เพราะสามารถทำงานได้สะดวก ได้ดินที่แน่นและมีคุณภาพ ถ้าทำในหน้าฝนอาจเกิดเหตุการณ์ดินไหลได้ (SCG Building Materials) ปรับระดับโดยใช้รถบดดิน(**รูปภาพที่ 5**) หรือเครื่องบดอัดดิน (**รูปภาพที่ 6**)ให้เรียบ จากนั้นถมทรายลงไปและใช้เครื่องบดให้เรียบ จากนั้นปูพลาสติก (สำหรับพื้นที่ที่ใช้ในอาคาร) เพื่อความเรียบเนียนยิ่งขึ้น

รูปภาพที่ 5 รถบดดิน

รูปภาพที่ 6 เครื่องบดอัดดิน

2. จากนั้นวางไม้แบบให้เท่าขนาดของห้อง (5.75 X 8.3 เมตร) และใช้แปรงขนาดใหญ่ทาน้ำมันที่ด้านในไม้แบบเพื่อป้องกันไม่ให้คอนกรีตติดไม้แบบ

3. ขั้นตอนต่อไปคือการคำณวนรอยต่อคอนกรีตก่อนเทพื้น เพื่อลดการหดตัวซึ่งจะนำไปสู่การแตกร้าว โดยการแบ่งพื้นที่ออกเป็น 4 ส่วนด้วยการนำไม้แบบมาวางชั้นเป็นส่วนๆ (**รูปภาพที่ 7**) แล้วจึงเทคอนกรีต



รูปภาพที่ 7 ไม้แบบ

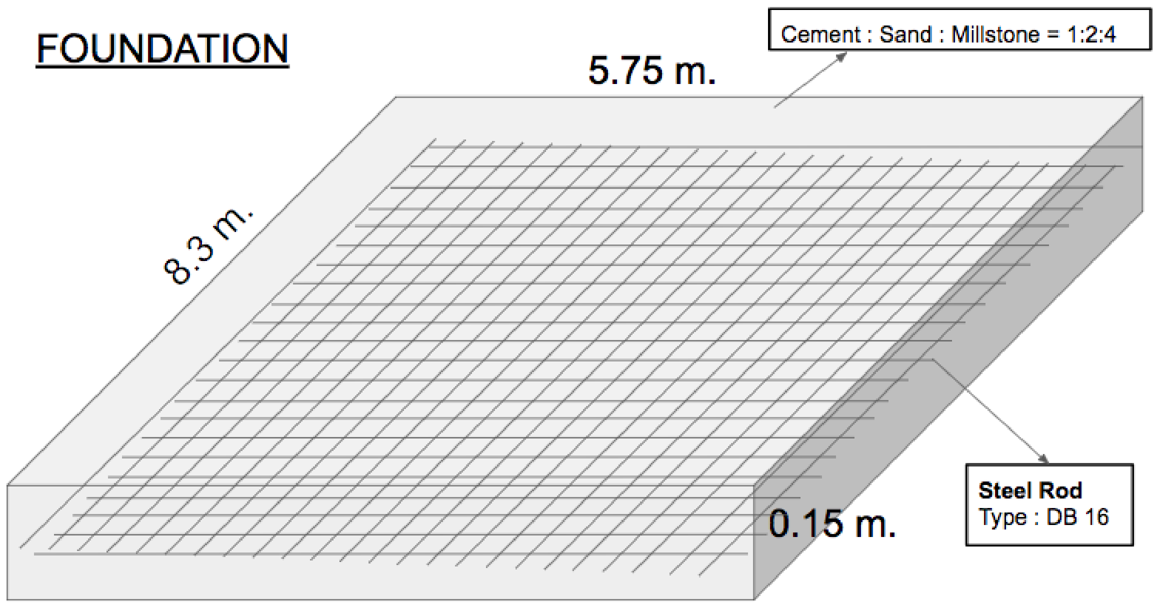
4. เตรียมไม้แบบ(คอนกรีต)ตามความสูงที่จะวางแหล็กเส้น
และวางไว้บริเวณจุดที่สามารถรองรับน้ำหนักทั้งเส้นได้
5. จากนั้น เริ่มวางเหล็กเส้นทั้งหมดสี่ชั้นตาม **ตารางรายละเอียดเหล็กเส้น**:

ตารางรายละเอียดเหล็กเส้น

ชั้นที่	ความสูง (ซม.)	จำนวน	ชนิด	ระยะห่าง (มม.)
4(บน)	12.5	38	DB16	200
3	9	22	DB16	250
2	7	22	DB16	250
1(ล่าง)	5	38	DB16	200

- ‘ความสูง’ คือ ระยะห่างจากพื้นถึงจุดศูนย์กลางของเหล็กเส้น
- ‘ระยะห่าง’ คือ ระยะห่างของเหล็กเส้นถัดไป

ตัวอย่าง: ชั้นที่หนึ่ง วางเหล็กเส้นชนิด DB16 (16 มม.) จำนวน 38 เส้นให้ขนานกับด้านกว้างของตึกคือ ด้าน 5.75 เมตร และวางให้ระยะสูงจากพื้น 5 ซม.



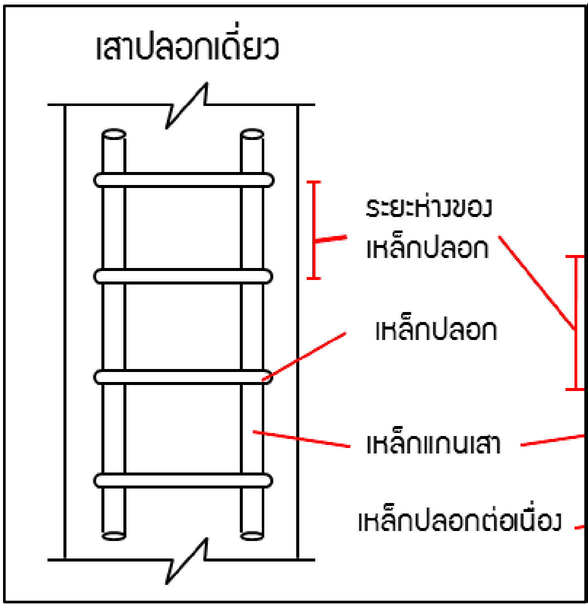
รูปภาพที่ 8 รายละเอียดการวางเหล็กเส้น และ ขนาดของฐานราก

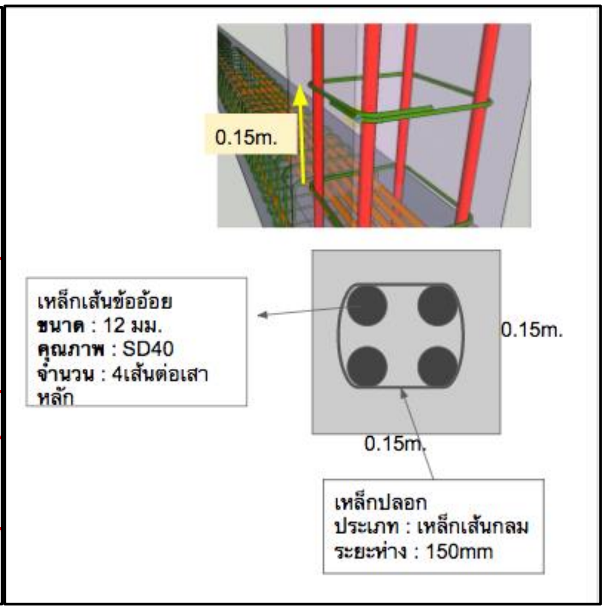
6. เสาหลักสามารถเลือกใช้ได้จาก 2 วิธี ดังนี้

6.1 เป็นเสาสำเร็จรูป ขนาด 15 ซม. X 15 ซม. ยาว 3.5เมตร หน้า 6 (รูปภาพที่9) ก่อนเทคอนกรีตบนฐานราก ให้วางเสานี้เป็นแนวตั้งบนพื้นให้มั่นคงก่อนเทคอนกรีตลงฐานราก

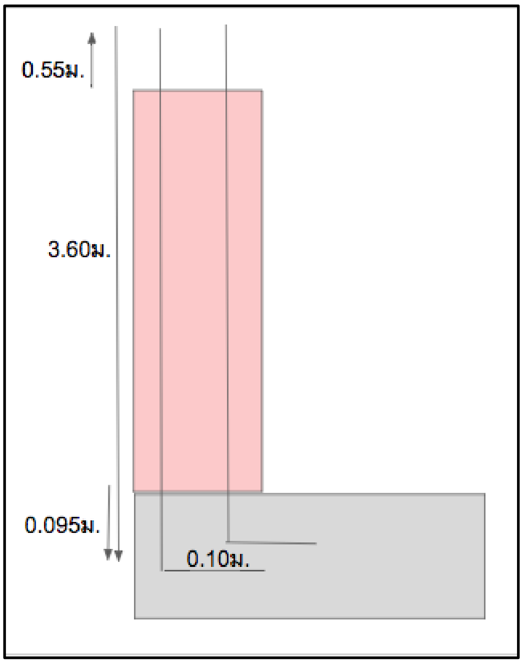
รูปภาพที่ 9 เสาเหล็กสำเร็จรูป ณ ร้านจื่อเต๋อ ต.วาวี เชียงราย

6.2 ก่อนเทคอนกรีตลงฐานรากใช้เหล็กเส้นข้ออ้อยหนา 1.6 มม. ความยาว เมตร โดยงอปลายด้านล่างให้มีความยาว 10 ซม. และปักลงไปในแม่แบบของฐานราก ลึก 9.5 ซม. (รูปภาพที่12) จึงเทคอนกรีต และวางไม้แบบสำหรับเสาหลัก6เสา แต่ละไม้แบบมีขนาด 15ซม. X 15ซม. และล้อมด้วยเหล็กปลอกแบบเดี่ยว (รูปภาพที่11) ระยะห่างของเหล็กปลอกประมาณ 15 ซม. (รูปภาพที่10) เพื่อก่อคอนกรีตสูงขึ้นเป็นเสาหลักที่ตรงและแข็งแรง
และนำไม้แบบออกหลักจากคอนกรีตแข็งตัว



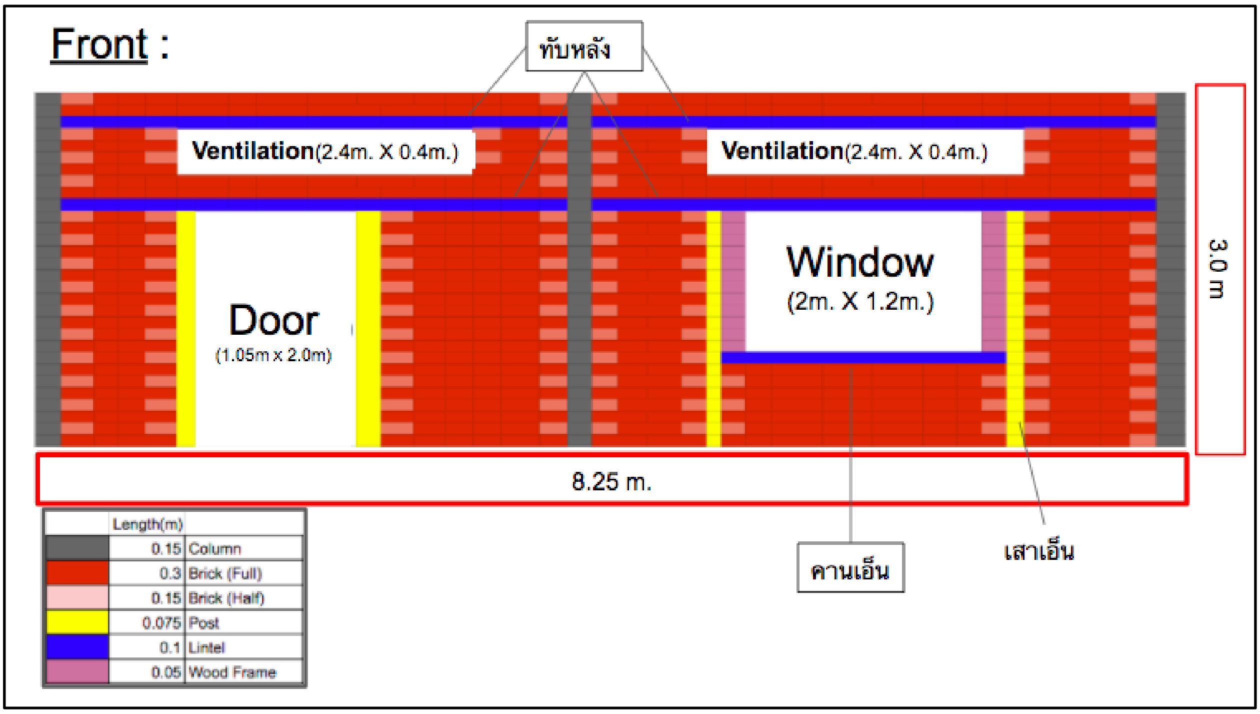


รูปภาพที่ 10 องค์ประกอบเสาหลัก **รูปภาพที่11 รายละเอียดเสาหลัก**



รูปที่ 12 สัดส่วนเหล็กเส้นภายในเสาหลัก

7. เกี่ยวเหล็กเส้นทั้งหมดที่เป็นส่วนของคานทับหลัง และ เสาเอ็น ไว้กับโครงเหล็กเสาหลัก เพื่อเตรียมก่อคอนกรีตในการรับน้ำหนักอิฐและเพื่อทำช่องว่างที่แข็งแรงสำหรับการใส่ประตูและบานหน้าต่าง



รูปภาพที่ 13 ภาพสองมิติจำลองของด้านหน้าอาคารห้องเรียน

8. เริ่มเทคอนกรีตเป็นแนวยาวให้เสร็จเป็นแนวๆไป(หน้า 14) เมื่อเทคอนกรีตครอบคลุมทั่วพื้นที่แล้ว จำเป็นต้องใช้ที่จี้เขย่าเพื่อป้องกันไม่ให้เกิดฟองอากาศแทรกตัว
ห้ามเทน้ำหรือผสมน้ำขณะเทคอนกรีตลงบนพื้นที่ เนื่องจากจะทำให้ความแข็งแรงของคอนกรีตลดลง ยกเว้นการบ่มที่ถูกวิธีเท่านั้น

9. ทำให้ระดับคอนกรีตเท่ากันโดยใช้เกรียงเหล็กฉาบให้ทั่วพื้นผิวเพื่อความเรียบเนียนและเงางาม **ไม่ควร**ปรับระดับโดยใช้น้ำเท หรือ โรยผงปูนในขั้นตอนนี้

10. การบ่มคอนกรีต

เพื่อเป็นการควบคุมและป้องกันมิให้น้ำในคอนกรีตระเหยออกจากคอนกรีตที่แข็งตัวแล้วเร็วเกินไป ซึ่งจะส่งผลต่อกำลังของคอนกรีตโดยตรง ดังนั้น หลังจากที่ผิวหน้าคอนกรีตแข็งตัวแล้ว จะต้องบ่มคอนกรีตให้มีความชื้นอยู่เสมอ เป็นเวลาอย่างน้อย 7 วัน กำลังของคอนกรีตจะค่อยๆ เพิ่มขึ้นเรื่อยๆ ตราบเท่าที่ยังมีความชื้นให้ปูนซีเมนต์ได้ทำปฏิกิริยากับน้ำ (Civilclub, 2010) สามารถทำโดยการใช้แผ่นผ้าพลาสติกคลุม (**รูปภาพที่ 14**)

รูปภาพที่ 14 การควบคุมความชื้นในซีเมนต์

10. เพื่อให้เป็นการดีที่สุดควรบ่มทิ้งไว้ในระยะเวลา 28 วันจึงจะเสร็จสิ้นขั้นตอนการทำฐานรากและสามารถใช้งานได้ทันที

พื้น

รูปภาพที่ 15: พื้นปูนขัดมัน

ขั้นตอนการทำพื้นปูนขัดมันสำหรับพื้นคอนกรีตเสริมเหล็ก

1. หลังจากที่เทคอนกรีตโครงสร้างและปรับระดับให้ได้ตามต้องการเสร็จแล้ว เมื่อคอนกรีตเริ่มแห้งหมาดๆ ให้โรยปูนซีเมนต์ผง หรือปูนซีเมนต์ผสม ลงบนผิวหน้า และขัดให้เรียบด้วยเกรียงเหล็ก

รูปภาพที่16 เกรียงเหล็ก

2. การลงน้ำยา Lithium Silicate หรือ Apoxy
ที่จะซึมเข้าไปในเนื้อคอนกรีตเกิดปฏิกิริยากับโครงสร้างทางเคมีในผิวคอนกรีต
ทำให้คอนกรีตมีความแข็งแกร่งขึ้น
3. ทำการขัดผิวปูนจนเรียบ ไม่มีรอยใบขัดหรือผิวหยาบเลย
ขบวนการนี้จะขัดจนให้ได้ผิวตามต้องการของเรา (ด้วยเครื่องขัดผิวใบเพชร)
4. การลง wax (Acrylic M-100) แล้วทำการขัดเพื่อให้เกิดความเงาตามต้องการ ตามรูปที่12

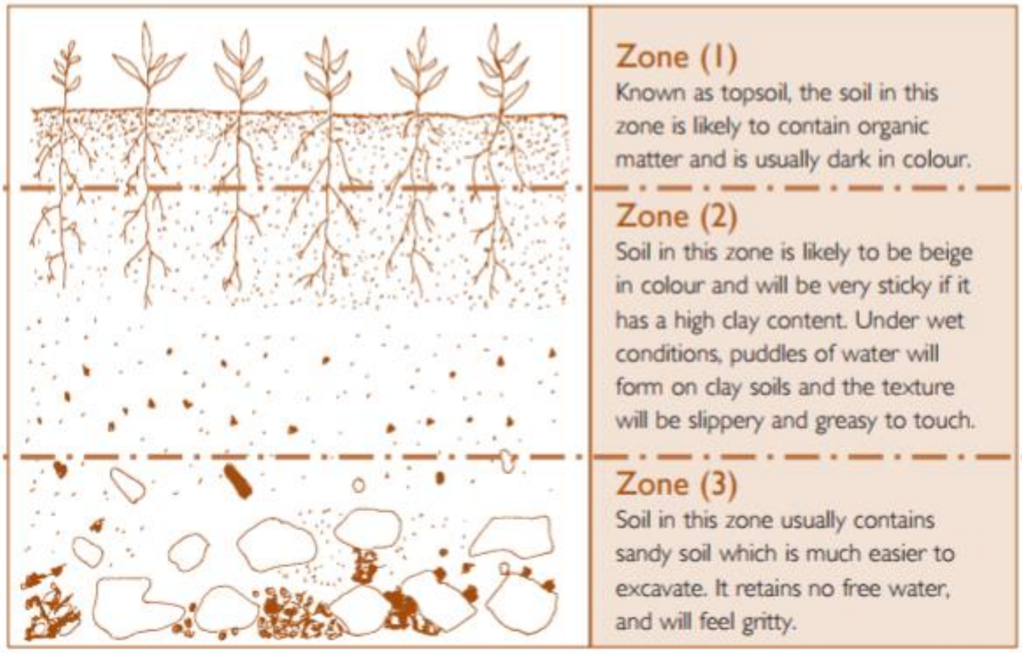
ผนัง/กำแพง

ผนังที่เราจะก่อขึ้นมานั้นจะถูกก่อด้วยวัสดุที่เรียกว่า 'อิฐบล็อกประสาน'
ซึ่งเป็นวัสดุที่ประกอบด้วยดินทรายและซีเมนต์
วัตถุดิบเหล่านี้จะถูกนำไปใส่ในเครื่องจักรที่เรียกว่าเครื่องอัดอิฐบล็อกประสาน
ซึ่งเครื่องนี้จะอัดส่วนผสมเข้าด้วยกันทั้งหมดและออกมาเป็นอิฐบล็อกประสานในขนาดที่ต้องการ
ซึ่งในกรณีนี้อิฐจะมีขนาดที่ ยาว 30 เมตร X กว้าง 15 เมตร X สูง 10 เมตร
หลังจากที่ได้อิฐมาแล้วการก่อสร้างของผนังจะสามารถทำได้เป็นขั้นตอนต่อไป

ขั้นตอนการเตรียมและทดสอบดินทราย

จากการทดลองนำดินทรายบริเวณโรงเรียนดอยเวียงวิทยามาทดสอบที่จุฬาลงกรณ์มหาสิทยาลัย และพบว่า คุณสมบัติของดินแดงนั้นต้งอมีความแห้งกร่าน และมีความชื้นน้อยที่สุด ดังนั้น ควรขุดเอาชั้นหน้าดินที่มีความชื้นออกก่อน และเลือกชั้นดินที่แข็งและแห้ง

เหมาะสำหรับการนำไปอัดเข้าเครื่อง เพื่อให้อิฐมีช่องว่างน้อยที่สุด จึงต้องใช้ดินทราย/ดินแดง ที่ไม่มีการอุ่มน้ำอยู่ภายใน ดังนั้น ดินชั้นที่3(ล่างสุด) เหมาะสมที่สุด



รูปภาพที่ 17 ชั้นเนื้อดินพร้อมคำอธิบาย

ทั้งนี้ทั้งนั้น ควรทดสอบก่อนน้ำไปใช้ด้วยวิธีนี้

1. เตรียมภาชนะโปรงใสตูนแบนเรียบและสามารถปิด-เปิดได้ และ ตระแกรงขนาด6มม.
2. นำเนื้อดินมาบดละเอียดผ่านตระแกรงช่อง
3. นำเนื้อดิน 1 ใน 3 ส่วน ของปริมาตร 2 ลิตรที่เตรียมไว้มาผสมน้ำที่มีความสูง 1ใน3ส่วน ของขนาดภาชนะโปรงใส
4. เติมเกลือ 2 ช้อนโต๊ะ
5. เขย่าให้เข้ากัน
6. วางทิ้งไว้ให้แยกตัว เป็นเวลา 30 นาที
7. เขย่าอีกทีแต่เป็นการเขย่าที่หมุนเบาๆเพื่อให้เนื้อทรายขยับตัวได้เล็กน้อย
8. และวางทิ้งไว้บนที่เรียบ นาน45 นาที จนกว่าระดับน้ำชั้นบนมีความใส

สุดท้ายนี้ ถ้าไม่เห็นการแยกตัวของก้อนทรายละเอียด หรือเนื้อดินมีความเหลวเกินไป ให้เอาทรายละเอียดมาเพิ่มความแข็งแรงและลดความชื้นออกจากเนื้อดิน

ขั้นตอนการเตรียมวัตถุดิบและอุปกรณ์

1. ดินแดงทราย แห้ง ละเอียด 2336 กก.
2. ปูนซีเมนต์ 584 กก. หรือ 15 ถุง
3. เครื่องอัดดินประสานชนิดโยก
4. อุปกรณ์การผสม และ บดละเอียด

5. พลาสติกป้องกันเนื้อดินติดเหล็ก

ขั้นตอนการผลิตอิฐบล็อกประสานโดยการใช้เครื่องอัดอิฐบล็อกมือโยก

1. นำซีเมนต์และดินทรายชั้นล่างที่มีความแห้งมาผสมในสัดส่วน 1:4 พร้อมกับด้วยน้ำในปริมาณน้อย(พอหมาด) จากนั้นผสมให้เข้ากันจนเนื้อซีเมนต์และเนื้อดินสร้างผสมละเอียดและไม่ติดกัน
2. นำแผ่นพลาสติกบางๆมารองที่แม่พิมพ์เพื่อป้องกันการติดของอิฐ
3. หลังจากที่ส่วนผสมเข้าที่แล้ว ให้ตักส่วนผสมนั้นไปเทใส่แม่พิมพ์ของเครื่องอัด(ภาพที่13) สำหรับการขึ้นรูป
4. วางแผ่นพลาสติกบางด้านบนเนื้อวัตถุดิบ และ ปิดแผ่นเครื่องอัดด้านบน
5. ดึงคันโยกเพื่ออัดส่วนผสมเข้าไปด้วยกัน จากนั้นให้ยกตัวอัดออกจากแม่พิมพ์เพื่อนำอิฐบล็อกออก
6. นำแผ่นพลาสติกออก เพื่อใช้ในรอบต่อไป
7. นำไปตาก ณ บริเวณที่ปราศจากความชื้น
8. ทำขั้นตอน 2-7 ไปเรื่อยๆจนกระทั่งอิฐที่ต้องการใช้นั้นพอ
9. ตากอิฐไว้ ประมาณ 2-3วัน เพื่อให้อิฐแห้งสนิทและแข็งแรง

รูปภาพที่18 เครื่องอัดอิฐบล๊อกประสาน

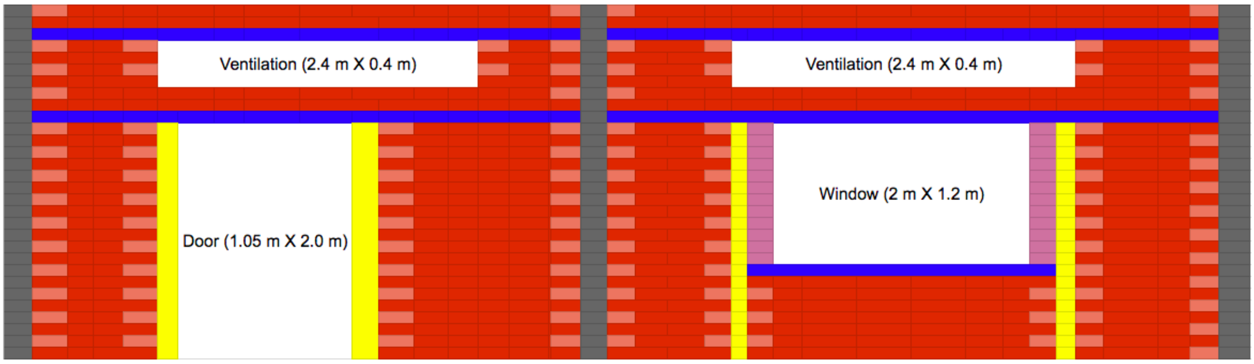
รูปภาพที่19 รูปร่างอิฐบล๊อก

ขั้นตอนการเตรียมช่องว่างเพื่อใส่ประตูและหน้าต่าง

ใช้คอนกรีตและเหล็กเพื่อสร้างคาน ทับหลังและ เสาเอ็น ตามขั้นตอนหน้า 31-34

ขั้นตอนการก่อผนัง

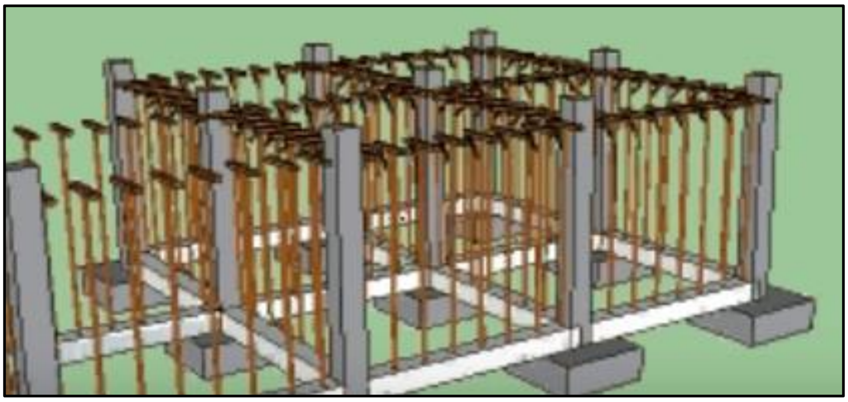
1. นำอิฐบล็อกประสานมาก่อรอบฐานของโครงสร้างจนครบชั้น โดยแต่ละชั้นจะเริ่มจากขนาดอิฐที่แตกต่างกัน ตามภาพด้านล่าง



รูปที่ 20 ภาพสองมิติจำลองการเรียงของอิฐบล๊อกและส่วนประกอบอื่นๆ

(สีแดงอ่อนจะมีขนาดครึ่งหนึ่งของอิฐ คือ 0.15 เมตร X 0.15 เมตร X 0.10 เมตร และสีแดงปนน้ำตาลเข้มจะเป็นอิฐเต็มก้อนขนาด 0.30 เมตร X 0.15 เมตร X 0.10 เมตร)

2. ค่อยๆก่อจากด้านซ้ายไปด้านขวา ด้านล่างขึ้นด้านบน และเว้นระยะช่องว่างตามขนานของบงกบประตูหรือวงกบหน้าต่างเสมอ
3. จากนั้นนำท่อนไม้ไผ่ที่ผ่านการเคลือบและทำความสะอาดแล้ว ซึ่งมีขนาดสามเมตรนั้นมายึดใส่รูของอิฐบล็อกเพื่อทำให้โครงสร้างนั้นแข็งแรงขึ้น (รูปภาพที่21)



รูปที่ 21 โครงไม้ไผ่เตรียมสอดอิฐบลอกประสาน

4. หลังจากที่ทำการใส่ไม้ไผ่ไปแล้วนั้น ให้ทำการใส่คอนกรีตไปในรูที่เป็นช่องว่างระหว่างไม้ไผ่กับอิฐบล็อกจนกระทั่งรูถูกเติมจนสนิท

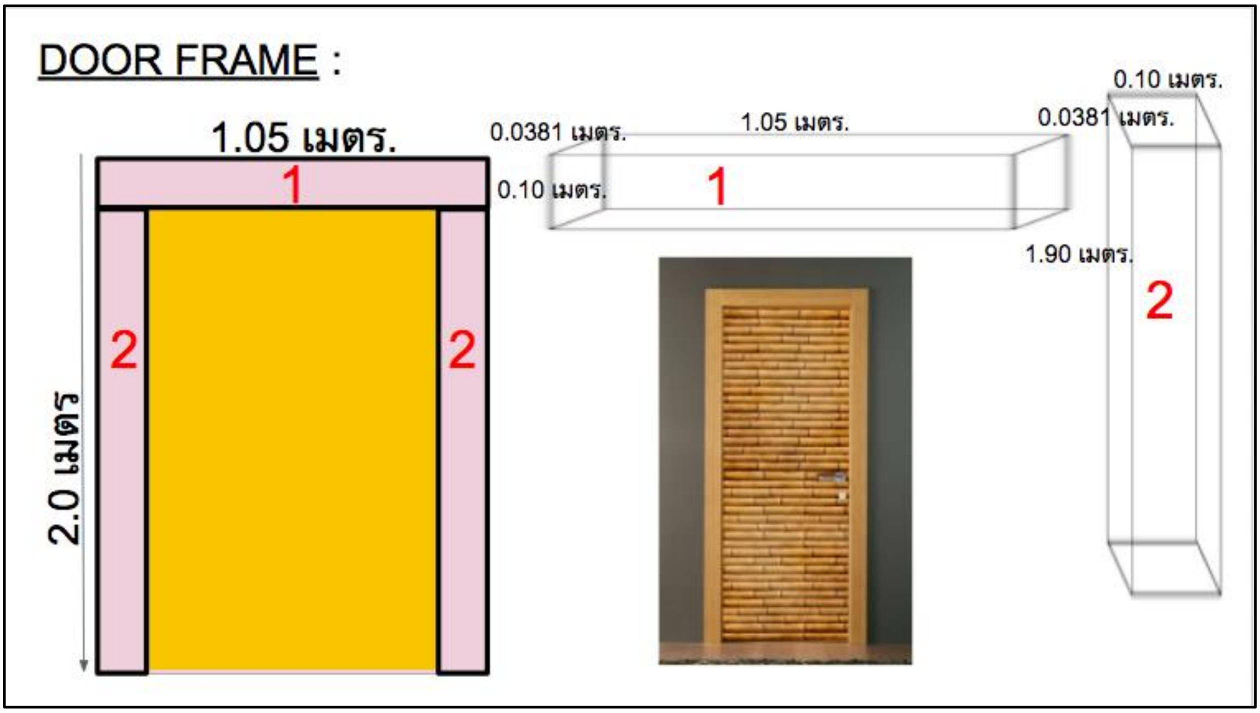
ขั้นตอนการทาแลคเกอร์

1. เตรียมพื้นผิว ด้วยการล้างพื้นผิวให้สะอาด ปราศจากฝุ่น สี น้ำมัน สารเคลือบผิวต่างๆ
2. ปล่อยทิ้งไว้ให้แห้งสนิท
3. ทา น้ำยาเคลือบเงาอิฐ จำนวน 2 -3 เที่ยว (กรณีเชื้อราและตะไคร่น้ำให้กำจัดด้วยน้ำยากำจัดเชื้อราและตะไคร่น้ำ *เบเยอร์ โมลด์ฟรี เอ็ม-001*)

ประตู

มีขนาด (1.05 เมตร X 1.80 เมตร) ส่วนประกอบมีดังนี้

1)Door Frame (วงกบประตู)



รูปภาพที่ 22 ขนาดวงกบประตู

1. เตรียมขนาดไม้ไผ่ตามสัดส่วนดังภาพ ท่อนไม้ไผ่หมายเลขหนึ่ง จำนวน1ท่อน และท่อนไม้ไผ่หมายเลขสอง จำนวน2ท่อน
2. เมื่อก่อเสาเอ็นข้างประตูเสร็จและแห้งเรียบร้อย ให้ใส่ท่อนไม้ไผ่หมายเลขสองก่อนทั้งสองฝั่ง และค่อยใส่ท่อนไม้ไผ่หมายเลขหนึ่งใช้วิธีเดียวกับการทำวงกบหน้าต่าง ในหน้าที่31-34

2) Door Sheet (บานประตูสานไม้ไผ่)

รูปภาพที่ 23 ตัวอย่างแผ่นไม้ไผ่สาน

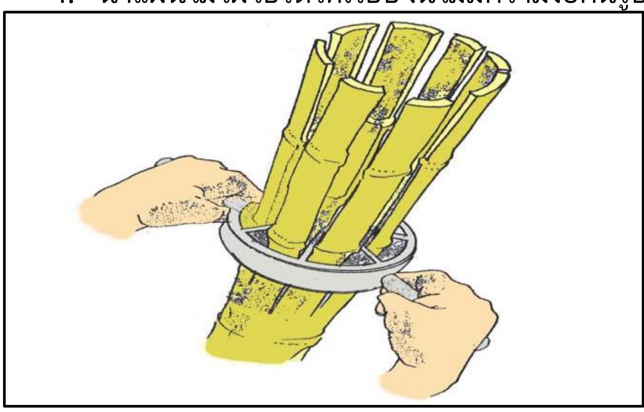
ขั้นตอนการเตรียมบานประตูไม้ไผ่สาน

วิธีที่1 (รูปภาพที่24)

1. ตัดส่วนที่เป็นปลายรากหรือบริเวณที่สีแต่กต่างจากส่วนอื่นออก
2. ผ่าไม้ไผ่ให้ออกเป็นซีกเล็กลง 6 ซีก บริเวณปลายไม้ไผ่ก่อน เหมือนการตัดขนมเค้ก
3. ใช้เหล็กเล็ก3เส้นขั้นให้ได้เป็น6ส่วน
4. จากนั้น นำส่วนที่อ้าไปใส่ในวงกลมที่เตรียมไว้เพื่อช่วยให้เนื้อไผ่แยกออกจากกันได้ง่ายขึ้น
5. ดันจดไม้ไผ่แยกออกเป็น6ซีก และนำซีกเล็กๆมารวมกัน เพื่อสานประตูไม้ไผ่ตามวิถีชาวบ้าน

วิธีที่2 (รูปภาพที่25)

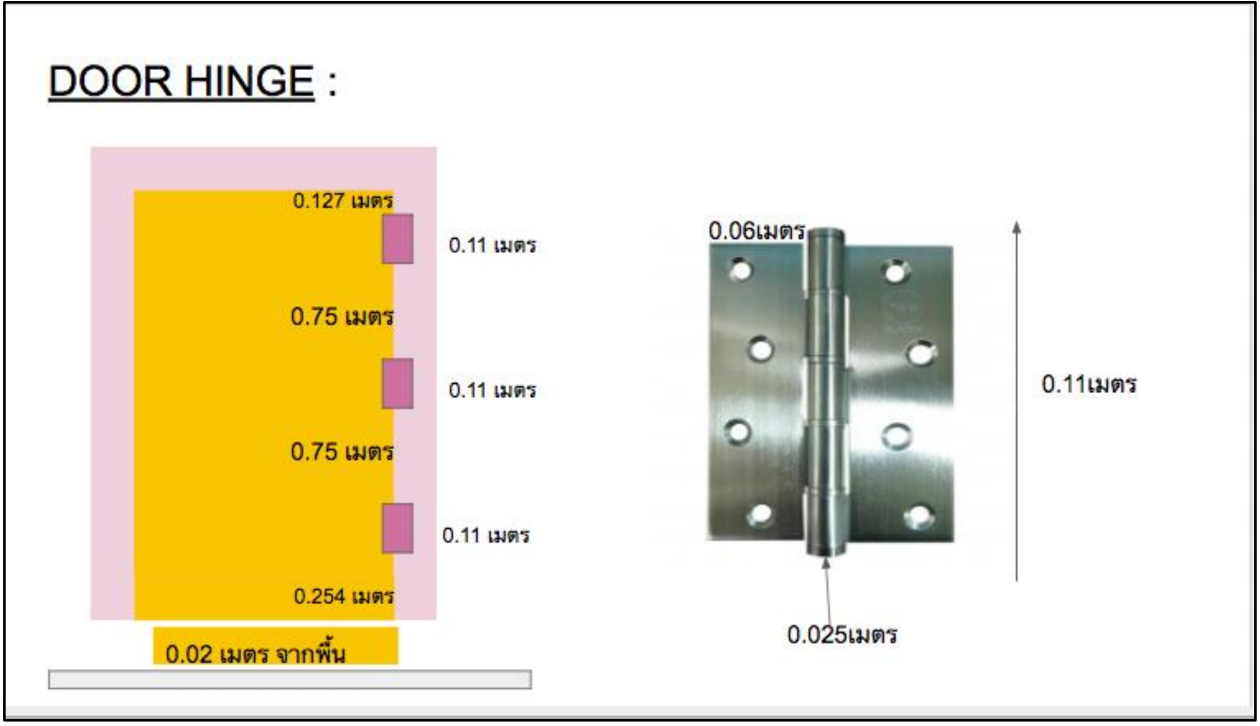
1. ผ้าไม้ไผ้ ให้เป็นแผ่นสีเหลี่ยมผืนผ้า
2. กีดเนื้อไม้ไผ่บางๆเพื่อให้มุมของเนื้อไม้อ้าได้เพิ่มขึ้น
3. ตัดส่วนที่เป็นป้องออกให้หมด เพื่อไม่ให้มีส่วนที่ยื่นออกมาจากแผ่นประตู
4. นำแผ่นไม้ไผ่ไปรีดให้เรียบจนไม่มีความงอคืนรูป



รูปภาพที่24 การผ่าไม้ไผ่

รูปภาพที่25 ไม้ไผ่ที่ถูกรีดแบน

3)บานพับประตู



รูปภาพที่ 26 สัดส่วนตำแหน่งของการติดตั้งประตูด้วยบานพับ

1. วัดระยะที่บริเวณที่จะติดบานพับและใช้ดินขีดเอาไว้ที่สันขอบประตูที่ทำไว้
2. ขุดเนื้อไม้ไผ่ให้เกิดร่องตามขนาดบานพับ
3. เจาะน๊อตเข้าไปในด้านบานพับลงบนสันขอบประตู
4. นำบานประตูไปเทียบกับวงกบประตูและขีดเส้นบริวณที่จะติดกับบานพับประตู
5. ทำข้อที่2-3 บนวงกบประตู เพื่อเตรียมยึดบานพับลงบนวงกบ

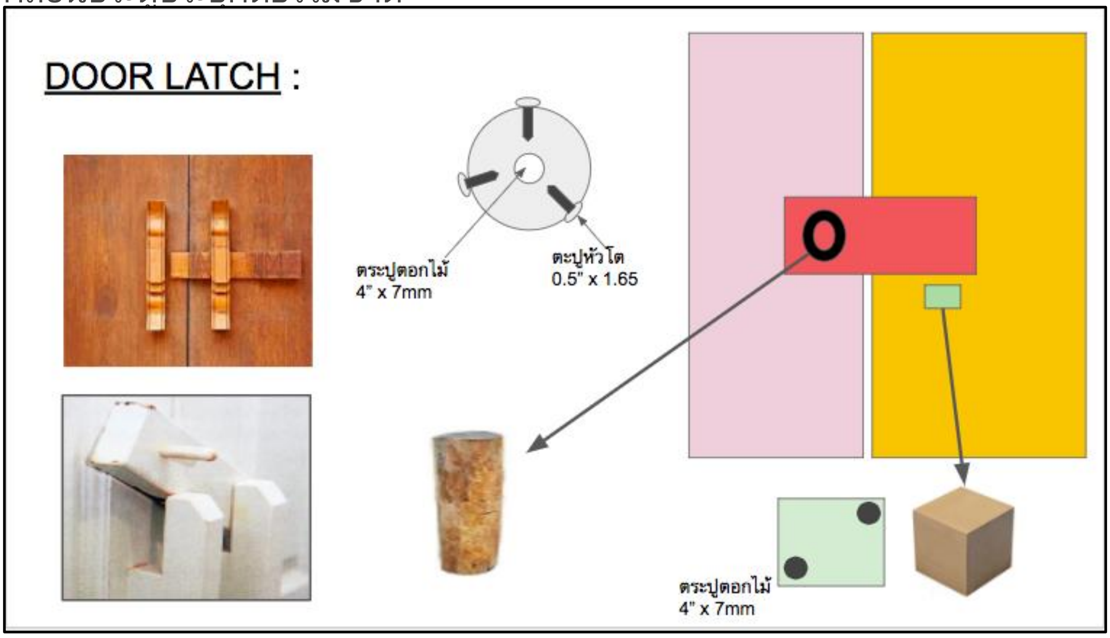
4) กลอนประตู 2 แบบ ดังนี้

1. กลอนประตูโบราณ

ใช้ท่อนไม้ตัวยู ตอกติดกับบริเวณที่ต้องการบนบานประตู ละอีกท่อนให้ติดอยู่กับวงกบประตู และใช้ไม้ท่อนขนาดที่สามารถสอดเข้าช่องว่างได้ในการเปิด-ปิดของประตู

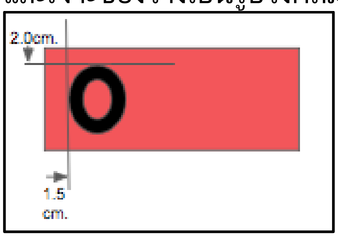
รูปภาพที่27 ตัวอย่างกลอนประตูโบราณ

2. กลอนประตูประยุกต์ธรรมชาติ

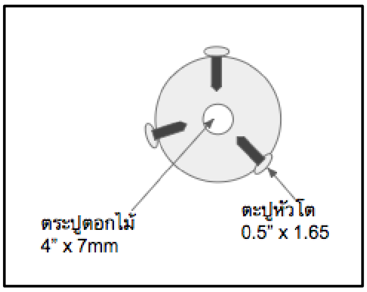


รูปภาพที่28 รายละเอียดกลอนประตูแบบหมุนได้

1. เตรียมวัสดุ อุปกรณ์ดังนี้
    a. ท่อนไม้ทรงกระบอกยาว 7 ซม. เส้นผ่านศูนย์กลางกว้าง 3 ซม.
    b. ท่อนไม้ทรงปริซึมสี่เหลี่ยม ยาว13ซม.กว้าง3 ซม. สูง 8ซม. และเจาะช่องว่างเป็นรูปวงกลม ตามรูป

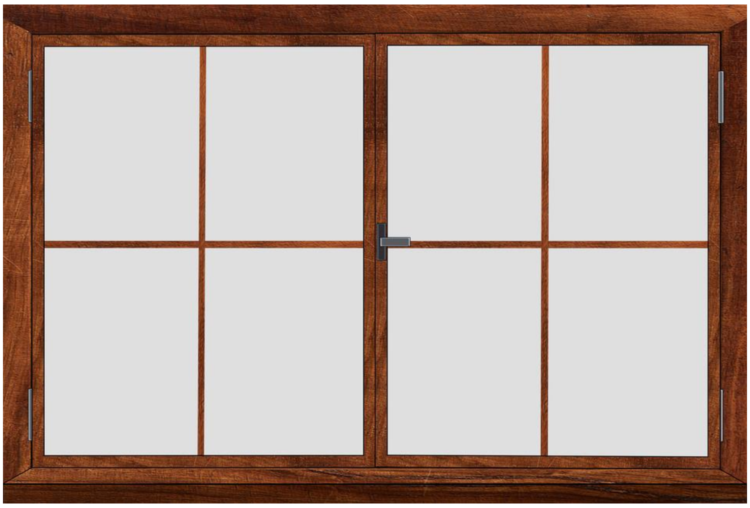
    

    (ห่างจากขอบด้านซ้าย 1.5 ซม. และด้านบน 2ซม.)
    c. ตระปูตอกไม้ ขนาด4” หัว7มม. หรือขนาดใกล้เคียง
    d. ตระปูหัวโต ขนาด0.5” หัว1.65มม. หรือขนาดใกล้เคียง
    e. ท่อนไม้ทรงสี่เหลี่ยมจัตุรัส ยาวด้านละ 2-3ซม.
2. ตอกตระปูตอกไม้(1c) ลงบนท่อนทรงบอก (1a) ไว้ตรงวงกบประตู สูงจากพื้นประมาณ1เมตร
3. สอดท่อนไม้ทรงปริซึมสี่เหลี่ยม(1b) เข้าไปในท่อนไม้ทรงกระบอกที่ได้ตอกลงวงกบแล้ว
4. ตอกตระปูหัวโต (1d) 3ตัว ตามภาพนี้ เพื่อคั่นท่อนไม้ด้านในไม่ให้เคลื่อนที่หรือหลุดออกมา



5. ตอกท่อนไม้สี่เหลี่ยมจัตรัส(1e) ลงบนบานประตู วัดระดับให้ท่อนไม้ที่ติดอยู่ฝั่งวงกบประตู สามารถวางลงบนท่อนนี้เป็นแนวนอน180องศาพอดี
6. ทำขั้นตอนทั้งหมดกับด้านในอาคารเรียนเช่นกัน เพื่อเป็นการล๊อคประตูไม่ให้เปิดออกตลอดเวลา

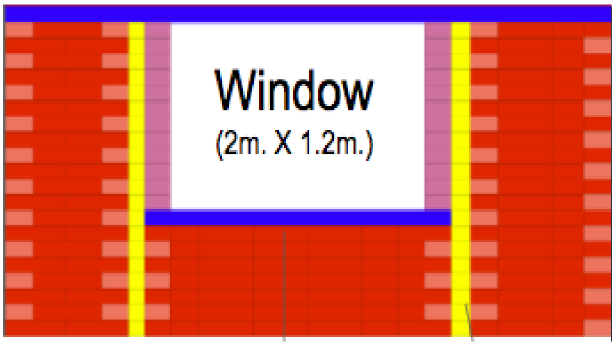
หน้าต่าง



รูปภาพที่ 29 ตัวอย่างหน้าต่างสำเร็จรูปชนิดบานเปิด

ขั้นตอนการใส่วงกบไม้แบบเปียก (กรณีที่วางเหล็กเส้นแล้วแต่ยังไม่ได้เทซีเมนต์ทับหลังและเสาเอ็น)

1. เตรียมวงกบขนาดที่เล็กเหมาะสมที่พอเหมาะสำหรับทำเสาเอ็นและทับหลัง ขนาดวงกบประมาณ 2.1เมตร X 1.3เมตร โดยให้ขอบบงกบด้านละ 2-3 ซม.
เหลื่อมล้ำเข้าในบริเวณทับหลังและเสาเอ็น
และใช้เชือกเอ็นหรือน้อตผูกกับเหล็กเส้นของเสาเอ็นและคาน ให้ได้ตำแหน่ง
และทดสอบระดับน้ำทั้งแนวนอนและแนวดิ่ง



รูปภาพที่30 ภาพสองมิติจำลองหน้าต่าง **รูปภาพที่31 การวัดระดับน้ำของวงกบ**

2. วางไม้แบบเพื่อเตรียมเทคอนกรีตลงเหล็กเส้นเพื่อทำทับหลังและเสาเอ็น และวัดระดับน้ำอีกรอบจนได้ระดับน้ำที่ถูกต้อง
3. เริ่มเทคอนกรีตตามความเร็วที่เหมาะสม
4. ทิ้งคอนกรีตไว้ 6 ชม. หรือจนคอนกรีตแห้งสนิท และนำไม้แบบออก

ขั้นตอนการใส่วงกบไม้แบบแห้ง (กรณีมีทับหลังและเสาเอ็นเรียบร้อยแล้ว)

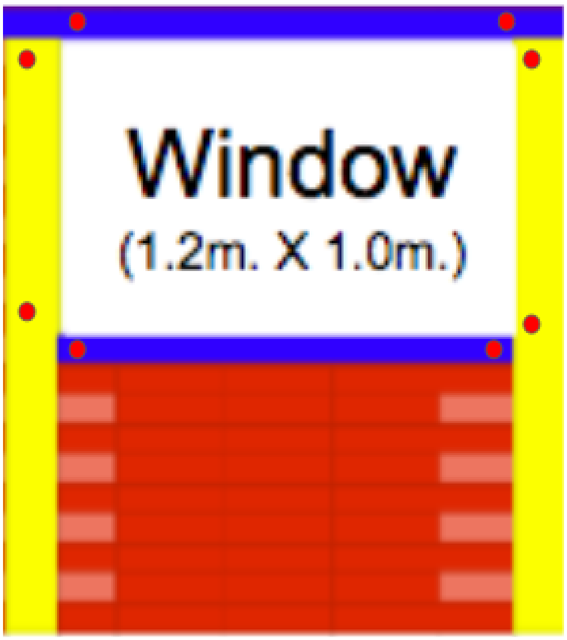
อุปกรณ์ที่ต้องเตรียม

วิธีทำ

1. จับเซี้ยมวงกบประตูให้เรียบร้อย
2. มาร์คจุดและเจาะเพื่อยึดน็อต ควรใช้สว่านเจาะเพื่อความแม่นยำ (สว่านขนาด7 มม. เจาะลึกลงไป 35-40 มม.)
3. ฝังบุกพลาสติกเบอร์ 7 ลงในรูที่เจาะไว้
4. ยึดวงกบกับผนังด้วยน็อตเบอร์ 7
5. เก็บช่องว่างระหว่างผนังกับแพงกับวงกบด้วยการยาแนวซิลิโคน
6. ปิดหัวจุกน็อต

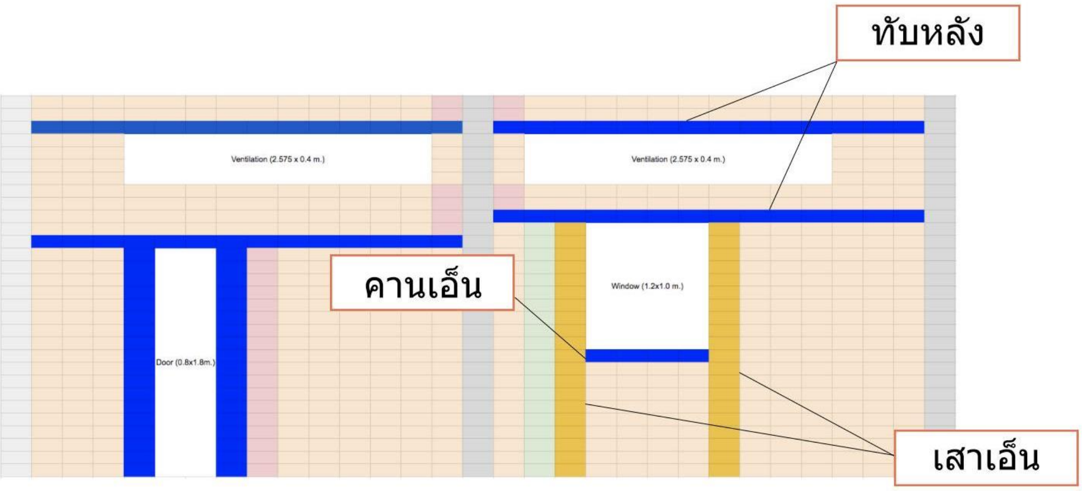
วิธีการใส่หน้าต่าง

1. หน้าต่างสำเร็จรูปจะมีลวดขึงติดอยู่ภายใน ดังนั้นจึงต้องเจาะน็อตไว้บนกำแพงเพื่อขึงหน้าต่างไว้ตำแหน่งตามรูปนี้

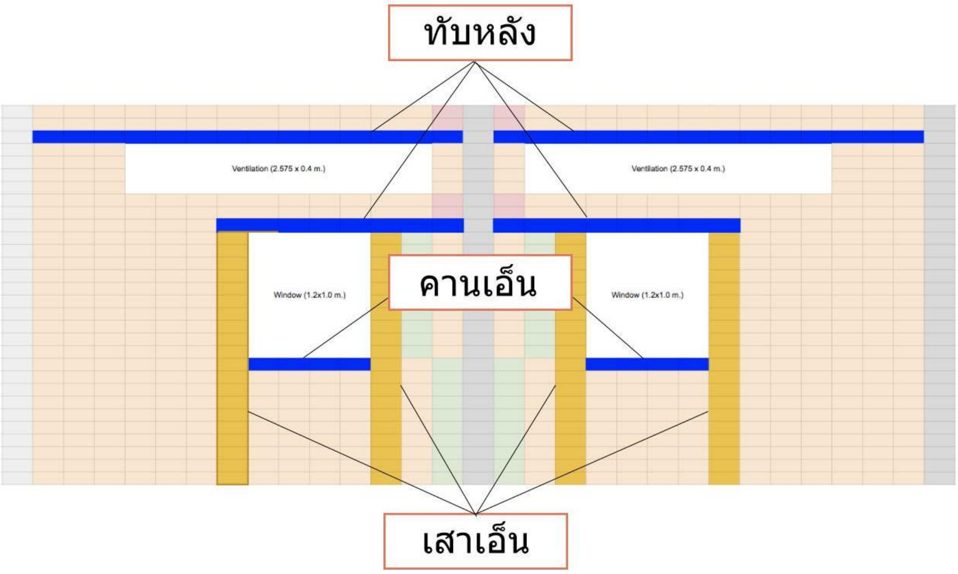


รูปภาพที่32 ตำแหน่งการเจาะน็อต

2. เกาะพลาสติกชั้นนอกสุดออก และนำลวดที่ติดอยู่กับหน้าต่างมาขึง
3. วัดระดับน้ำให้ได้ระดับ
4. ปิดช่องโหว่ด้วยปูนซีเมนต์ที่ใช้ก่อเสาเอ็นและคาน
5. เคลือบด้วยน้ำยาเคลือบเบเยอร์
6. และค่อยแกะพลาสติกป้องกันออกเป็นขั้นสุดท้าย



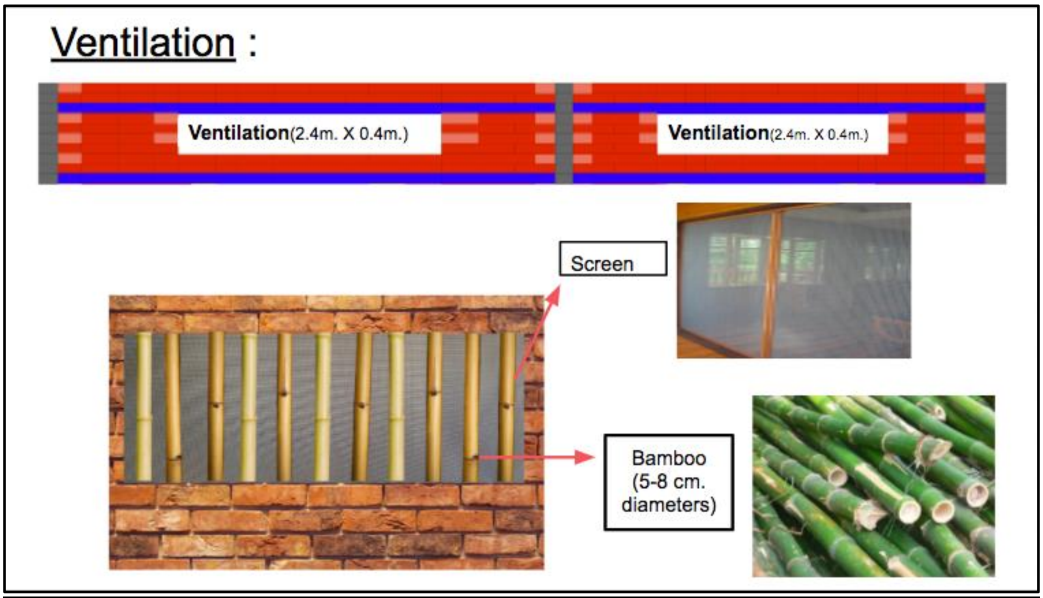
รูปภาพที่33 คานเอ็น ทับหลัง และ เสา (ด้านหน้าตัวอาคาร)



รูปภาพที่34 คานเอ็น ทับหลัง และ เสา (ด้านหลังตัวอาคาร)

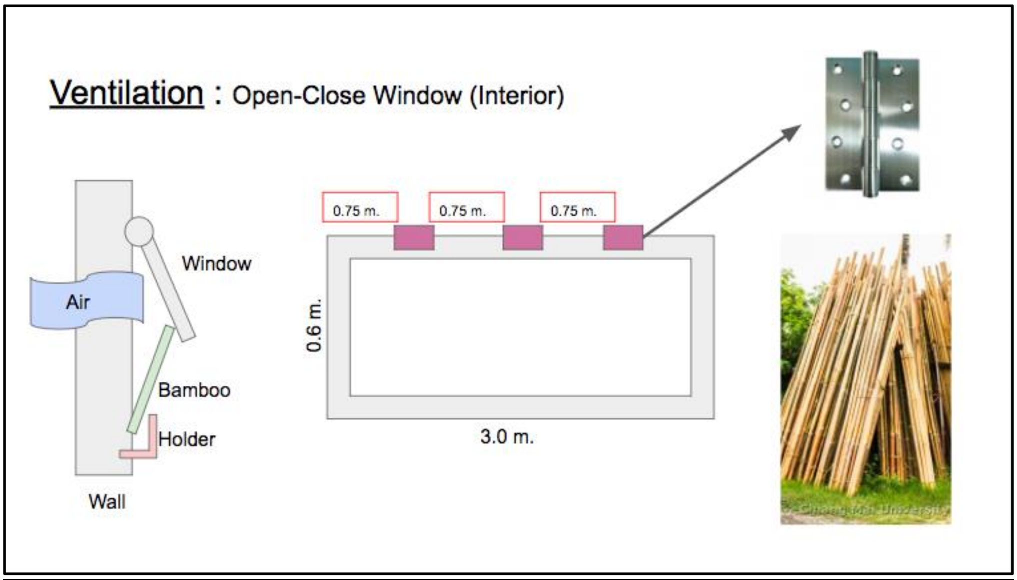
ช่องระบายอากาศ

_______ขณะก่ออิฐกำแพง รูบนอิฐจะต้องนำไม้ไผ่มาคั้นทั้งหมด16ลำต้นต่อ1ช่องระบายอากาศ ตามภาพนี้



รูปภาพที่35 รายละเอียดและวัสดุการทำช่องระบายอากาศ

ช่องว่างจากด้านในตัวอาคารห้องเรียน
จะยึดมุ้งลวดติดไว้ด้านในเพื่อไม่ให้แมลงหรือสิ่งอันตรายเข้าไปด้านในตัวอาคาร
เพื่อป้องกันตัวอาคารจากสิ่งอันตรายภายนอก นอกจากนั้น ยังมีหน้าต่างปิด-
เปิดเพื่อป้องกันลมหนาวในฤดูหนาว และเปิดถ่ายเทอากาศร้อนในฤดูร้อนได้ด้วยเช่นกัน ตามภาพด้านล่างนี้

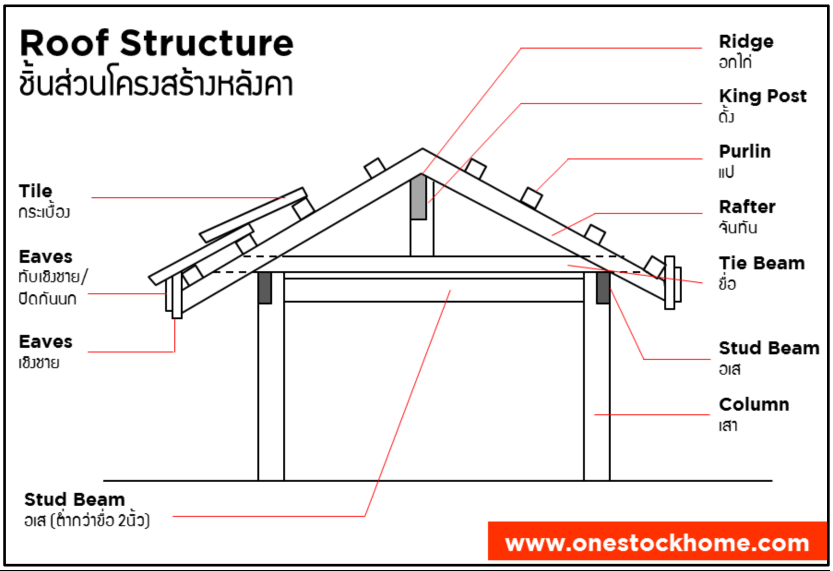


รูปภาพที่36 รายละเอียดการติดบานหน้าต่างสานใบไผ่แห้งภายในตัวอาคารของช่องระบายอากาศ

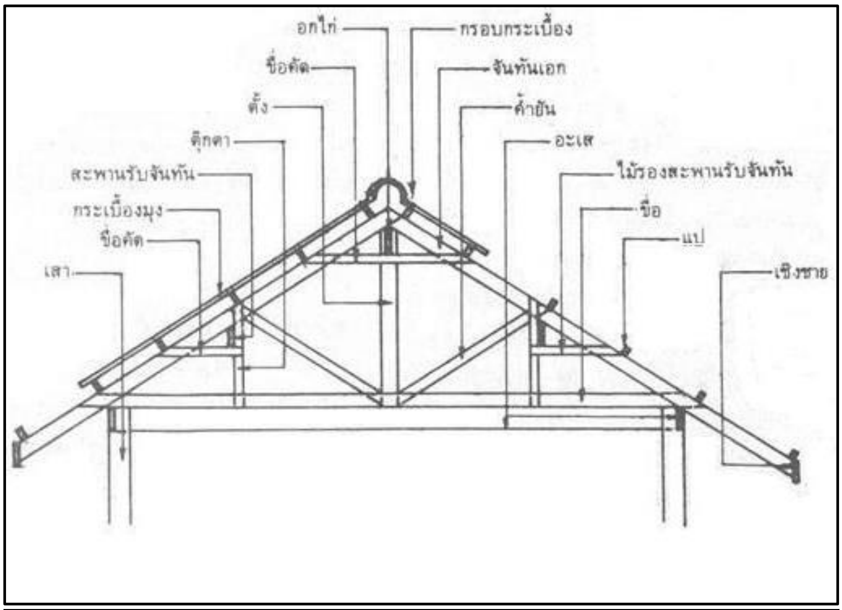
จัดเตรียมหน้าต่างใบไผ่สานหรือตองกิ่งสานให้ได้ขนาดตามรูป(3.0เมตรX0.6เมตร) จำนวน 4 บาน และเกาะบานหน้าต่างกับกำแพงโดยใช้บานพับขนาด10ซม. และใช้น๊อตขันให้แน่น
จากนั้นสร้างตัวขั้นแท่งแอล(สีแดง) เพื่อให้ต้นไผ่สามารถยึดรหว่างบานหน้าต่างกับที่ขั้นได้

รูปภาพที่37 ใบไผ่สานตากแห้ง (คล้ายไม้กวาดทางมะพร้าว)

หลังคา



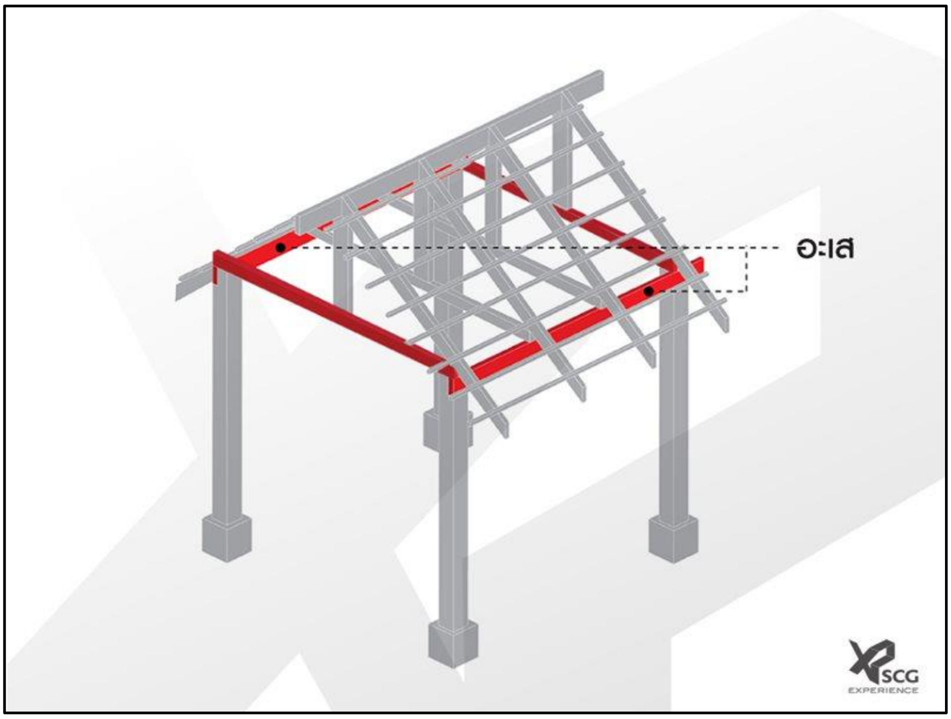
รูปที่38 ชิ้นส่วนโครงสร้างหลังคา



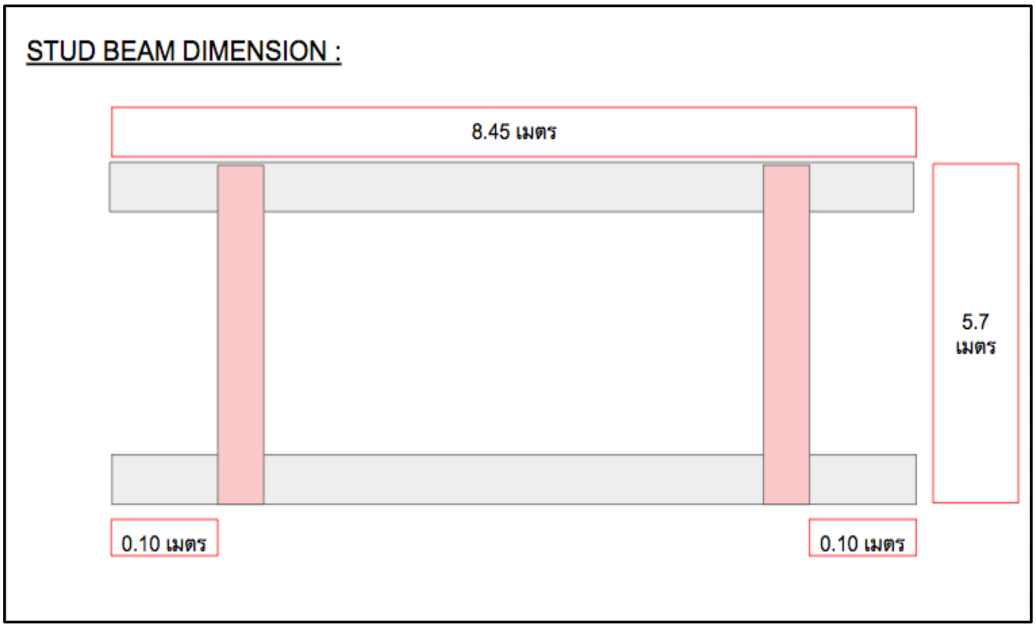
รูปภาพที่39 ชิ้นส่วนโครงสร้างหลังคาโดยละเอียด

โครงสร้างหลังคามีเลือกใช้ มีดังนี้

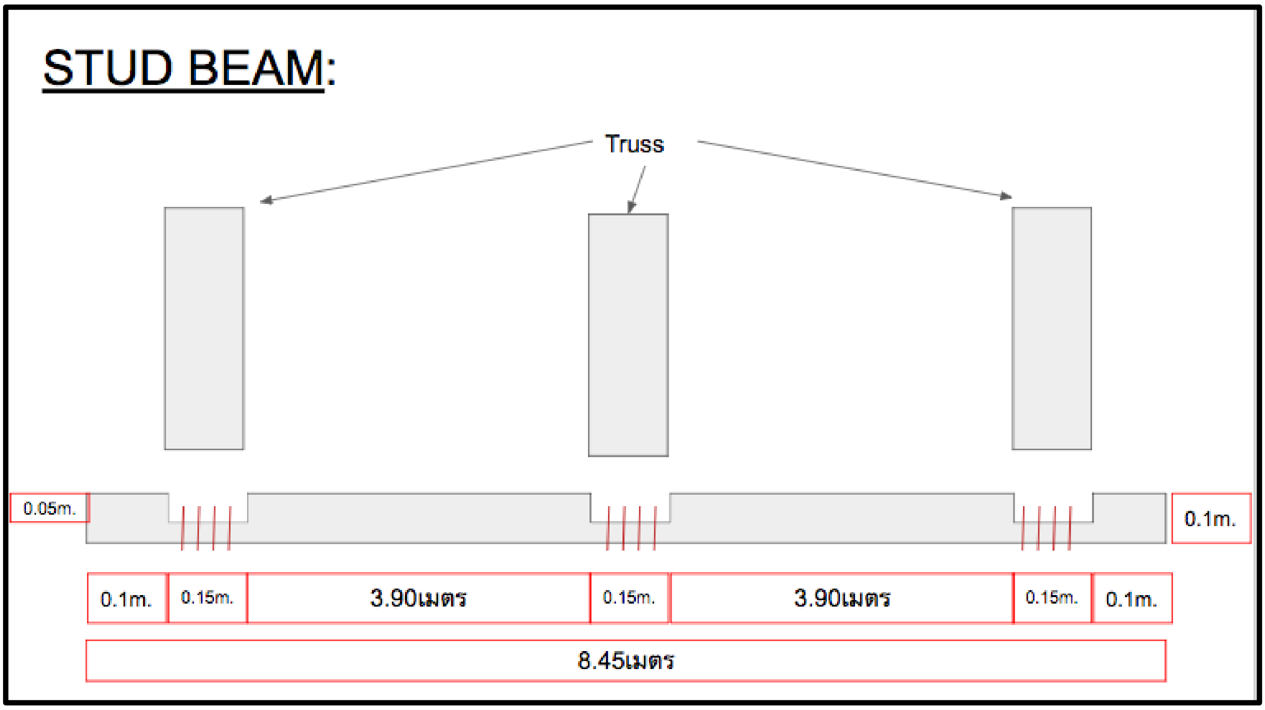
1. อะเส (Stud Beam) : ทำจากคอนกรีต วางตามระนาบชั้นกำแพงที่สูงที่สุด ขนาดตามรูปภาพที่41



รูปภาพที่40 ส่วนของอะเส

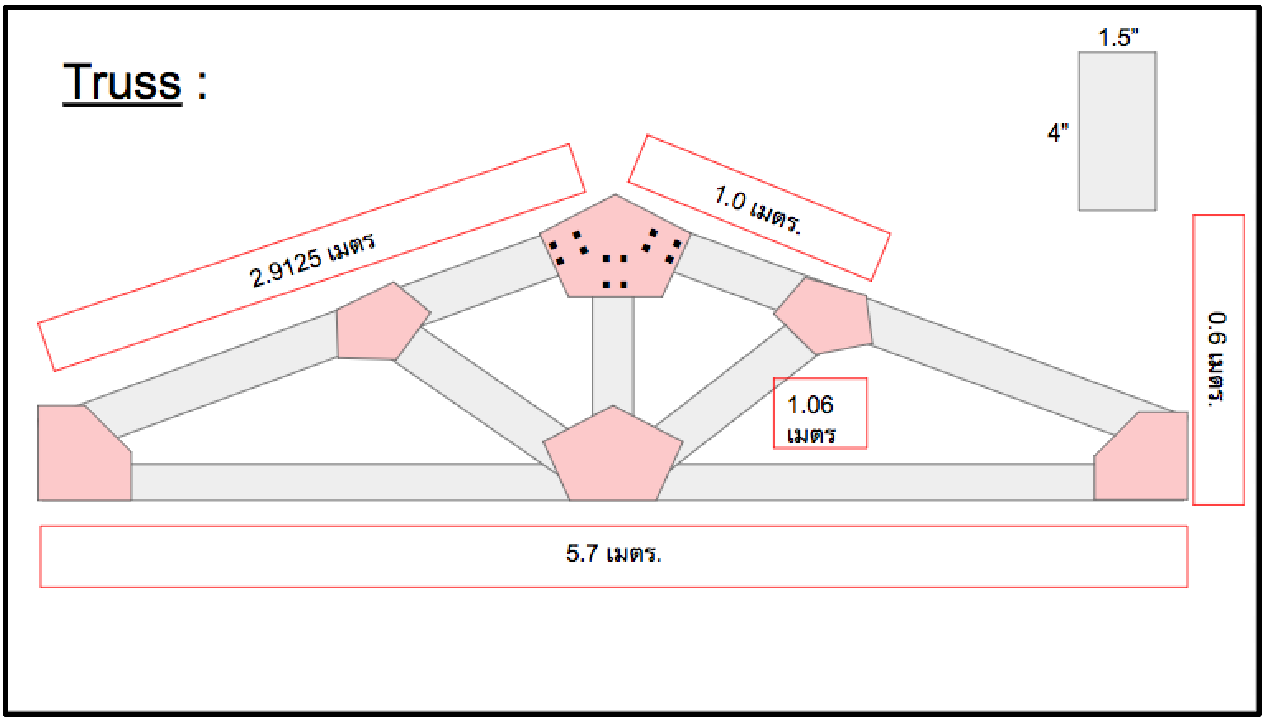


รูปภาพที่41 ขนาดของอะเส



รูปภาพที่42 สัดส่วนของอะเสและตำแหน่งการวางโครงยึด

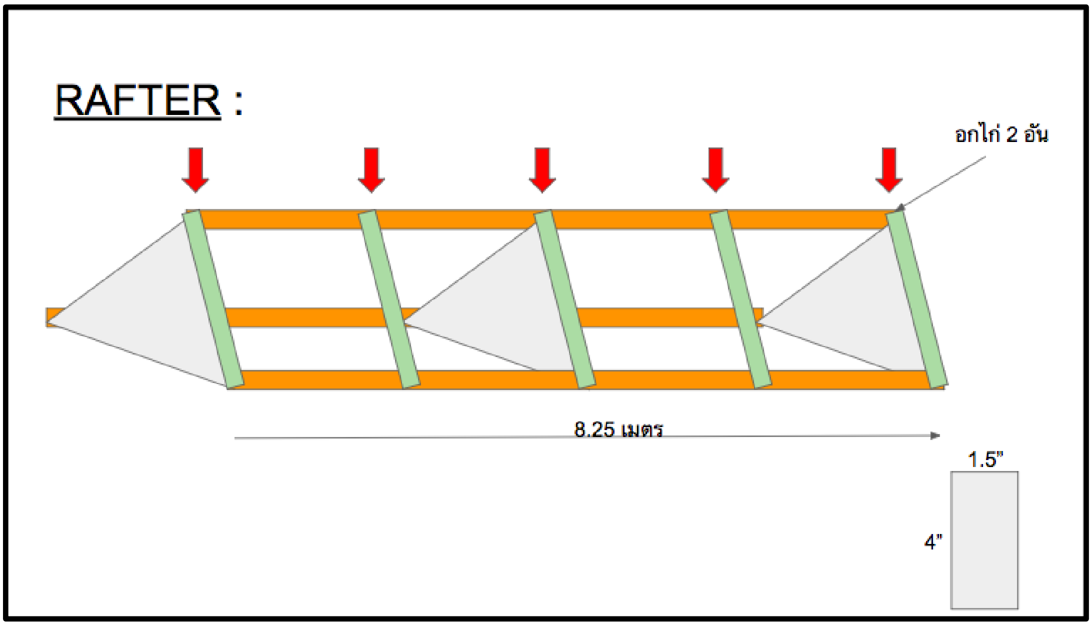
2. โครงยึด (Truss) : ประเภทที่เลือกใช้เป็นแบบตามรูปภาพที่43 มีส่วนประกอบเป็น จันทัดเอก ดั้ง ค้ำยันและอเส สามารถสร้างได้จาก2วัสดุ
    a. เป็นท่อนเหล็กกล่องไม้ขีดเชื่อม 3 ชุด มีรูปร่างและขนาดดังนี้



รูปภาพที่43 ขนาดและโครงสร้างของ

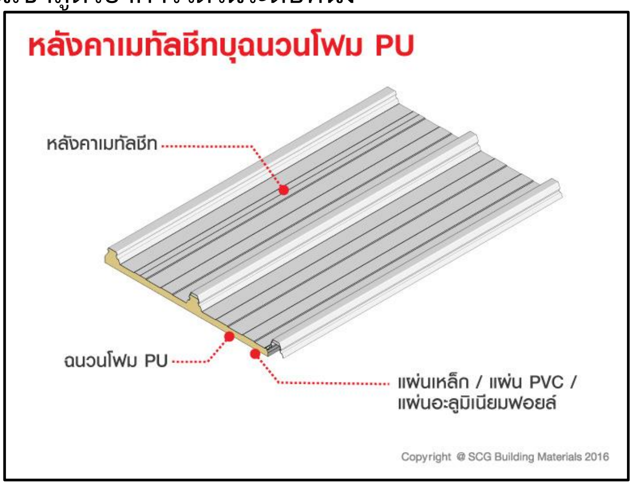
b. เป็นท่อนไม้จากบริเวณรอบข้างแต่ต้องมีความหนาของลำต้นพอสมควรที่จะรับน้ำหนักแผ่นหลังคา และเชื่อมท่อนไม้ได้ดังรูปภาพที่43 ในภาพแผ่นสีแดง
เป็นแผ่นเหล็กแบนและบางขนาด 6มม. และใช้น๊อต 4 ตัว
ต่อการเชื่อมไม้1ท่อนกับแผ่นเหล็ก เจาะน๊อตไซส์ M12 บนตำแหน่ง ตามรูปภาพที่43
และทำขั้นตอนนี้กับการเชื่อมไม้และเหล็กทุกต้น

หลังจากได้เตรียมโครงยึดครบสามชุดแล้ว ให้นำไปวางไว้ตามระยะของตำแหน่งที่กำหนดไว้ใน รูปภาพที่42 และต่อโครงยึดทั้งสามอันด้วย อกไก่2ท่อน ด้านบนของโครงยึด ตามรูปภาพที่ 44



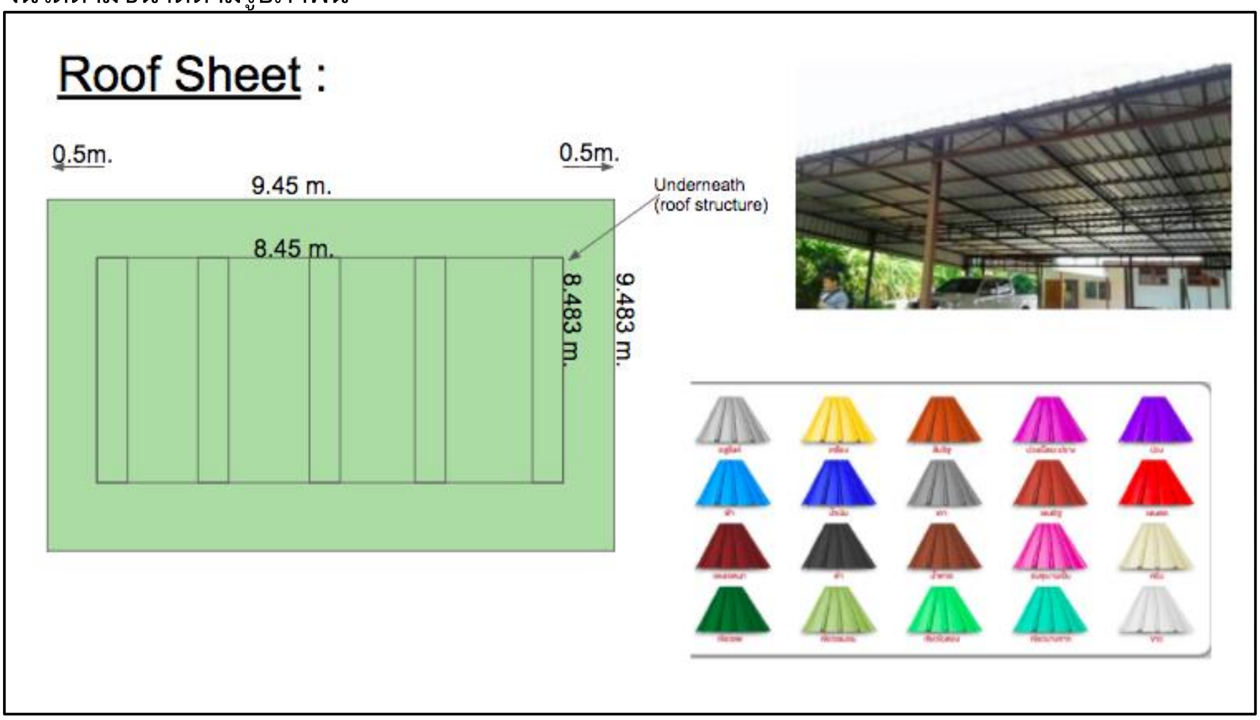
รูปภาพที่ 44 จำนวนและตำแหน่ง ของจันทัน

3. จันทัน (Rafter) : เป็นส่วนที่ใช้สำหรับรองรับแผ่นหลังคา จำนวนและระยะห่าง กำหนดตาม(สีเขียว) รูปภาพที่ แต่ละฝั่งจะ มี5จันทัน ในอาคารหลังนี้ไม่จำเป็นต้องมี แป เพราะขนาดไม่ได้มีขนาดใหญ่มาก
4. แผ่นหลังคา เมทัลชีท (Metal Sheet) : เป็นหลังคาที่มีฉนวนความร้อน ป้องกันความร้อนเข้าสู่ตัวอาคารได้ในระดับหนึ่ง



รูปภาพที่45 ส่วนประกอบหลังคาพียูโฟมเมทัลชีท

การวางแผ่นหนังคาให้วางชั้นล่างขึ้นชั้นบน ดังนั้นส่วนของชิ้นบนจะทับชิ้นล่าง จนได้ตามขนาดตามรูปภาพนี้



รูปภาพที่46 สัดส่วนของหลังคา

การบำรุงรักษา

<u>การบำรุงรักษาอาคารอิฐดิน</u>

_______อิฐดินนั้นไม่ควรสัมผัสกับน้ำโดยตรงเนื่องจาก คุณสมบัติของดินเมื่อพบเจอของเหลงหรือ น้ำ จะทำให้เกิดการสลายรูปซึ้ง อาจจะทำให้กำแพงขาดความสมดุลได้ ดังนั้น ถ้าเกิดรอยรั่วให้รีบหาซื้ออาคิริคทาผนังบ้าน มาทาทันที

ข้อควรระวัง : ไม่ควรทาทับผนังที่มีความชื้นอยู่ ควรรอให้ผนังแห้งสนิทเสียก่อน

<u>การถนอมไผ่โดยวิธีธรรมชาติ</u>

(คัดย่อจากหนังสือ “ไม้ไผ่ สำหรับคนรักไผ่”)

หลักการคือ การทำลายสารพวกแป้งและน้ำตาล ในเนื้อไม้ไผ่ ซึ่งเป็นอาหารของแมลงให้หมดไป แมลงก็เลยไม่มากิน

1. การแช่น้ำ ตั้งแต่ 3 วันถึง 3 เดือน แช่ได้ทั้งน้ำจืด และน้ำทะเล

2. การใช้ความร้อน หรือการสกัดน้ำมันจากไม้ไผ่ เพื่อทำลายแหล่งอาหารของแมลงในเนื้อไผ่ ทำไดวิธีคือ *การ ต้ม และปิ้งไฟ*

- *การต้ม* จะทำให้เนื้อไม้นุ่ม
- *การปิ้ง* จะทำให้เนื้อไม้แข็งแรง และแกร่งขึ้น

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Appendix B : Cost Analysis

Part	Materials	Weight	Units	Cost	Amount	Total (Baht)
Foundation	**Steel Rods (DB16)**	15.80	kg/ 10m.	359.00	120.00	43080.00
	Cement (Portland)	50.00	kg./ bag	140.00	44.00	6160.00
	Renting Formwork	-	sq.m.	-	-	3000.00
	Sand	4546.00	kg.	500.00	3.03	1515.33
	-	3.03	m^3	-	-	-
	Sand Stone	9128.00	kg.	1080.00	6.09	6572.16
	-	6.09	m^3	-	-	-
	Water	660.00	L	21.90	0.66	14.45
	-	0.66	units	-	-	-
	Wokers Fee	-	-	500 Baht/work/person	5.00	2500.00
Floor	**Lithium Silicate**	4.10	kg/Gallon	1616 B/ 400 sq.ft./37 sq.m.	6.00	9696.00
	Wax	3.48	kg/Gallon/6-7sq.m.	665Baht/ Gallon	8.00	5320.00
	Steel Trowel	-	-	150 baht	5.00	750.00
Wall	**Soil**	11486.00	kg.	-	-	0.00
	Column (Made)	15 x 15	m^3	545.00	6.00	3270.00
		3.50	m. tall	-	-	-
	Machine	0.3 x 0.1 x 0.15	m^3	14000.00	3.00	42000.00
	Cement (Brick)	584.00	kg.	118.00	15.00	1770.00
		14.60	bag	-		
	Cement (Beam)	391.00	kg.	118.00	10.00	1180.00

		9.78	Bags	-		
	Water	1770.73	L.	21.90	1.77	38.78
		1.77	Units	-		
	Lacquer	25.00	L/ Gallon	565.00	1.00	565.00
	Beyer Acrylic	3.50	L/ Gallon/31kg	360.00	3.00	1080.00
	Door Hinge	0.10	m.	60 Baht/ 3 hinges	1.00	180.00
	Hinge for Ventilation	0.10	m.	60 Baht/ 4 Hinges	3.00	720.00
	Screen	-	-	3000	4.00	12000
	Screw	4" x 7mm	-	40 / kg	3.00	120.00
		0.5" x 1.65mm	-	70 /kg	1.00	70.00
	Window	2.0x1.20	m^2	12300.00	1.00	12300.00
		1.20 x 1	m^2	6000.00	2.00	12000.00
	Workers Fee	-	-	500 Baht/work/person	5.00	2500.00
Roof	**Truss**	4" 2"	-	629 Baht / 20kg/ 6 m.	8.00	5032.00
	3 Ridges	4" 2"	-	629 Baht / 20kg/ 6 m.	6.00	3774.00
	Rafter	4" 2"	-	629 Baht / 20kg/ 6 m.	10.00	6290.00
	Eaves	4" 2"	-	629 Baht / 20kg/ 6 m.	4.00	2516.00
	Workers Fee	-	-	500 Baht/work/person	5.00	2500.00
	Closing Board	6" x 6 X 2or3m.	5.5 kg/board	60.00	12.00	720.00
	Rustproof Lacquer	0.88	L/ Gallon	260.00	2.00	520.00
	Metal Sheet	1.00	sq.m.	80.00	90.00	7200.00

Transportation	Truck	7.50	tons/ride	800 Baht/ride	13.12	10499.80
Total (Baht)						207453.52

Appendix C: Observations of Buildings and Campus

Rating Rubric For Only the Buildings

1	2	3	4	5
Non-functional (does not perform what it's said to do). Feature poses physical harm. Negatively impacts learning.	Fairly Functional (It is a temporary structure) - extent of damage is uncertain. Negatively impacts learning. Last less than 1 year.	Medium Function Small flaws, that does not affect the function of building during that time but will get worse if left unfix It could stay 1-3 years.	The feature performs quite okay, and it could be improved upon Would last up to 5 years. No/little effect on learning.	Does not need improvements or is sufficient enough for 5-10 years. Sturdy and no physical harm posed. Beneficial to learning environment.

Feature	**Kindergarten Classroom**				
Cleanliness	1	2	3	4	**5**
Comments: The classroom is clean for the school (not spotless and shining, but clean enough). There is enough space in the room for all students and the room is well kept.					
Cracks/Flaws	1	**2**	3	4	5
Comments: The classroom only has two windows in the entire building and they both face the same side of the building (facing the entrance to the entire school grounds).					
Colors	1	2	**3**	4	5
Comments: The exterior was bland without color unlike other grade classrooms and was only one color. There were no drawings/paintings of characters from shows or a friendly children design as seen in the other classrooms. There was a working TV and lots of stuff animals and blankets folded up neatly on the shelves. The tiles were ocean blue.					
Lighting	1	**2**	3	4	5

Comments: The interior of the classroom was well lit with electric fluorescent lights enough to fill the classroom with light. However, there was not enough natural light entering the room as there were only two windows present in the classroom. The windows didn't face the direction in which the sun's rays were aiming, so the light couldn't even go into the classroom. The second window did not seem to be in use because there were stuff blocking it from the inside.

Feature	**Grade 1 Classroom**				
Cleanliness	1	2	3	4	**5**
Comments: The classroom is clean for the school (not spotless and shining, but clean enough). There is larger than other classrooms and has enough space in the room for all students and the room is well kept.					
Cracks/Flaws	**1**	2	3	4	5
Comments: The classroom is very, very cold. The walls of the classroom have chain-linked fences. Students are also required to remove their shoes/sandals and the floor is very cold to be walking around barefoot. The walls are also flimsy. They are sturdy in the sense that they provide protection from the outside but if leaned into, the wall bends outwards.There is a thick metal framework in which the plaster wall sheets are inserted, but this is probably what provides a strong structure for the building to last so long. There are 2 parts in the room in which the plaster has cracked or broken exposing the outside.					
Colors	1	2	3	4	**5**
Comments: The exterior of the classroom building has drawings/paintings of dinosaur landscapes and dinosaurs which is attractive to younger students, especially. The dinosaurs were each a different color and the landscape was mostly green. The interior was decorated with papers and boards of learning aspects such as animals and their names in English, the English alphabet, previous work the students have done in the class, and others. The only surface having the most color is the floor which was covered in red tiles.					
Lighting	1	2	**3**	4	5
Comments: The classroom used electric fluorescent lighting that allowed the room to be well lit even with the door and all the windows closed. However, there was not a lot of natural light allowed into the room as it was only allowed to enter from the very top of the room (the rays of light didn't really fill the room, just the ceiling). They were also covered up by posters.					

Feature	Grade 2 Classroom				
Cleanliness	1	2	3	4	**5**
Comments: The classroom is clean for the school (not spotless and shining, but clean enough). This classroom is larger than other classrooms and has enough space in the room for all students and the room is well kept.					
Cracks/Flaws	**1**	2	3	4	5
Comments: The classroom is very, very cold. The walls of the classroom have chain-linked fences. Students are also required to remove their shoes/sandals and the floor is very cold to be walking around barefoot. The plastered wall sheets are falling apart and has lots of rust stains.					
Colors	1	2	3	4	**5**
Comments: Very colorful exterior, drawings/paintings of cartoons that are popular and very common (Totoro, Dragon Ball Z, Pokemon etc.). The interior was decorated with papers and boards of learning aspects such as animals and their names in English, the English alphabet, previous work the students have done in the class, and others. A LOT of posters.					
Lighting	1	2	**3**	4	5
Comments: The classroom used electric fluorescent lighting that allowed the room to be well lit even with the door and all the windows closed. However, there was not a lot of natural light allowed into the room as it was only allowed to enter from the very top of the room (the rays of light didn't really fill the room, just the ceiling).					

Feature	Grade 3 Classroom				
Cleanliness	1	**2**	3	4	5
Comments: The interior was decorated with papers and boards of learning aspects such as animals and their names in English, the English alphabet, previous work the students have done in the class, and others					
Cracks/Flaws	**1**	2	3	4	5

Comments: The classroom is very, very cold. The walls of the classroom have chain-linked fences. Students are also required to remove their shoes/sandals and the floor is very cold to be walking around barefoot. The walls are also flimsy. They are sturdy in the sense that they provide protection from the outside but if leaned into, the wall bends. The walls are peeling and the metal framework is rusting (also peeling).					
Colors	1	2	3	4	**5**
Comments: There were a lot of posters and colors on the walls. The walls were decorated similar to other classroom buildings with learning aspects and were mostly covered (couldn't really see a spot with just wall). The exterior of the classroom had drawings/paintings of space and the sky with names of different star patterns and constellations. Although the exterior was dark (since space is mostly black and there were dark blue and purple colors) the classroom still seemed to have a variance in color and still appeared to be attractive to the students. There is blue wallpaper surrounding the bottom of the classroom. The tiles are red and orange.					
Lighting	1	2	3	4	**5**
Comments: There were two giant "windows" around 4 ft by 5ft made of the metal fencing. The windows were not covered up so a lot of natural lighting was available. However, this poses the problem of rain coming in. Electrical lighting was good.					

Feature	**Grade 4 Classroom**				
Cleanliness	1	**2**	3	4	5
Comments: This classroom building has three different sections within it. The first section is a large classroom that is not very clean. The floors have a lot of dirt on them and in the classroom at the time of observation had a very dirty and large motorcycle parked in the corner of the classroom (the motorcycle was dirty with dirt and dust). However, the classroom overall was tidy due to the fact that it was simple setup with just picnic benches. The second section was a cooking space that had cats and dogs climbing all over the benches and stove (students reassured us that that cooking space was not a kitchen). Dogs wander in and out of the room more frequently (most likely because of the food) and they jump and walk all over the benches. The third section did not have a stove, but was also dirty and untidy with random furniture and items strewn on the ground: eg a giant blue hose underneath the table.					
Cracks/Flaws	**1**	2	3	4	5
Comments: This classroom did not have individual desks for each student as all other classrooms in the school have. Instead, there are benches for the students. The benches are filled with cracks, splinters, and the seat part of the bench is not balanced completely (the bench is like a curved line). The walls are made up of the wall/fence scheme similar to the previous classrooms discussed, however, it is a lot more fence than it is wall. The actual wall portion of the classroom is at the very bottom of the building, probably about 2 feet high and the rest of the wall is fence (extremely easy to see in and out of and most likely does not provide much coverage during rain and wind). However, the overall structure is sound due to the thick low cement wall.					

Colors	1	2	3	4	5
Comments: There are no colors on the exterior or interior and there are no posters/learning aspects in the classroom since there are no actual walls. The little amount of wall that is there is not colored and is white with several large dirty spots. The only poster existing is of food diet that is falling apart and writing ineligible. The tiles were the only thing that had color and patterns: red/orange flowers.					
Lighting	1	2	3	4	5
Comments: The most natural lighting of any classroom due to extreme exposure to the outside. The electrical lighting was good. It was just covered in cobwebs.					

Feature	**Grade 5 Classroom**				
Cleanliness	1	2	3	4	5
Comments: The classroom is clean for the school (not spotless and shining, but clean enough). This classroom is larger than other classrooms and has more than enough space in the room for all students and the room is well kept.					
Cracks/Flaws	1	2	3	4	5
Comments: The classroom did not have any noticeable flaws or cracks, it appears to be very well maintained and a great environment for the students. The only thing that can be mentioned is that there were fans in the room that were at both sides of the wall (parallel-wise) and so when on the produced wind could not reach the entire room, ceiling fans might be better.					
Colors	1	2	3	4	5
Comments: There were a lot of posters and colors on the walls. The walls were decorated similar to other classroom buildings with learning aspects and were mostly covered (couldn't really see a spot with just wall). The major color is a light bright green.					
Lighting	1	2	3	4	5
Comments: The wall facing the cafeteria is almost entirely made of windows. The bottom rows had doors and the top was made of glass. This provided a lot of natural lighting. Electricity was good,					

Feature	**Grade 6 Classroom**				
Cleanliness	1	2	3	4	**5**
Comments: The classroom is clean for the school (not spotless and shining, but clean enough). This classroom is larger than other classrooms and has more than enough space in the room for all students and the room is well kept. There were a few scattered items like boxes.					
Cracks/Flaws	1	2	3	4	**5**
Comments: The classroom did not have any noticeable flaws or cracks, it appears to be very well maintained and a great environment for the students. The only thing that can be mentioned is that there were fans in the room that were at both sides of the wall (parallel-wise) and so when on the produced wind could not reach the entire room, ceiling fans might be better.					
Colors	1	2	3	4	**5**
Comments: There were a lot of posters and colors on the walls. The walls were decorated similar to other classroom buildings with learning aspects and were mostly covered (couldn't really see a spot with just wall). The main colors are lime, white, and blue.					
Lighting	1	2	3	**4**	5
Comments: Not as much natural lighting as the 5th grade classroom and the windows have bars, but more than the rest. Electric lighting is good.					

Feature	Bathroom				
Cleanliness	1	2	3	**4**	5
Comments: The bathroom has tiles on the floor and walls and is clean (for a bathroom with no toilet). There is no toilet paper which is normal for Thailand and other countries in Asia and individuals need to squat over the 'toilet'. Overall, the bathroom is pretty clean for a bathroom and is only dirty with a little bit of wet dirt that enters at the bottom of individual's shoes/sandals.					
Cracks/Flaws	1	2	3	**4**	5

Comments: The roof does not cover all of the ceiling of the bathroom and may let rain enter if winds are strong (the bathroom is directly next to a larger building that has a roof that extends over the entirety of the bathroom).					
Colors	1	2	3	4	**5**
Comments: The colors of the exterior of the bathroom are green and pink and not just a simple one-color color. The interior is colored based on the color of the tiles (blue for boys). There are even tiles with fishies on the walls.					
Lighting	1	2	3	4	**5**
Comments: Electrical lighting turned on from the outside and is very bright due to the bathrooms being a small space. Natural lighting does seep through the corners and sides of the ceiling.					

Feature	Playground				
Cleanliness	1	2	3	**4**	5
Comments: The playground is dirty with normal dirt from children playing on the apparati and stepping on them but there was not an excessive dirty quality. There were no trash nor toys scattered around, so pretty much tidy,					
Cracks/Flaws	1	2	3	**4**	5
Comments: There are no noticeable flaws or crack in the playground. There is normal wear and tear on each apparatus but nothing very torn or in need of immediate replacement. Each apparatus was a bit too close to each other and so a more spacious playground could be enjoyed more and may result in the less likelihood of injury.					
Colors	1	2	3	4	**5**
Comments: The playground was very colorful. Each apparatus was a different, bright color and positively added to the overall welcome of the playground.					

Feature	Cafeteria

Cleanliness	1	2	3	4	**5**
Comments: The cafeteria is clean and well kept. The floors are tile and clean (students are to leave their shoes/sandals just outside the entrance of the cafeteria. The cafeteria is very large and spacious, enough to fit the entire school and teachers.					
Cracks/Flaws	1	**2**	3	4	5
Comments: The cafeteria also has the walls/fence scheme. It is a lot more fence than it is wall. The actual wall portion of the classroom is at the very bottom of the building, probably about 2-3 foot high and the rest of the wall is fence (extremely easy to see in and out of and most likely does not provide much coverage during rain and wind).					
Colors	1	2	**3**	4	5
Comments: There are pillars in the cafeteria space that are blue and the tile floors are also blue. We observed the cafeteria on Children's day and so there were plenty of colorful decorations and balloons so it is unsure if the cafeteria is actually colorful or not.					

Other Spaces	
Staff Room	Comments: Staff room is tightly packed. Light green color, but overall structure was clean, smooth, and strong. The windows are like the 5th and 6th grade classrooms. Electricity worked.
Other Bathrooms	Comments: Extremely dirty and smelly. Mold growing inside and outside. There was no electrical lighting.
Walkways	Comments: Some walkways were dug and shaped like stairway, but most were just a dirt slope with slabs of tiles or cement bricks. Poses hazards.
Library	Comments: Pale pink and blue and no windows. It was locked so didn't get to see the interior.
Terrain	Comments: Mountainous. Dirt roads with giant potholes. There is a giant pond behind the school.
Natural Materials	Comments:Most houses were made with bamboo trunks and leaves..

Appendix D: Table of Features from Grades 1-4 Drawings

Grade 1

Current School			Dream School		
Feature	Recurrency	Notes	Feature	Recurrency	Notes
Door	2	outlined just the door in red	Trees and Nature	10	
Entire Building	1	they drew a picture of their building and then scribbled red all over it	People	10	

Grade 2

Current School			Dream School		
Feature	Recurrency	Notes	Feature	Recurrency	Notes
Upper Window Frame	3	(underneath the roof around the building)	Pathways	1	outlined defined, connecting from building to building
Roof	1		Pathways with Railings	3	meandered and defined
Desk Legs	1		Swings and Playground	3	some has just swings and some with an elaborate playground (seesaw, slides)
			2 story building	1	area on the second floor to fish
			Fantasy Battlefield	1	robots and laser guns and fire breathing creatures
			4 story Building	1	each floor dedicated to each grade
			River with a bridge	2	between where they line up and where they learn, and b/w cafe. and building, the rivers has fish

			Flowers	1	EVERYWHERE: on buildings, ground

Grade 3

Current School			Dream School		
Feature	Recurrency	Notes	Feature	Recurrency	Notes
Windows	7	window doors (to open the window) and the actual windows were colored initially red and were colored over in red after being draw in in another color	Pathways	6	Connected to every building
Door	5	entire doors colored in red	2 Story Building	2	2 rooms dedicated to each grade
Grass	2	patches of grass colored in red	Flowers	4	bunched together like bushes
Hole at the bottom of the classroom's wall	1	the very bottom portion of the wall outlined in red	4 Building Complex	1	Buildings are adjacent to each other
			Windows with Doors	1	Windows with 2 doors opening out
			4 Story Building	2	With each grade labeled inside classroom
			Multi-Story Building	3	5,7,9 Floors high
			Restroom inside the Library	1	access to the outside with a roof
			Meeting Hall	1	Multi story
			Dorm	1	A grade labeled in each classroom
			Restrooms	2	Separated males and females, one connected and one not
			Pond with fishes	2	In the middle of the campus
			Other Buildings		tea house, canteen, mushroom greenhouse, water house to

					water plants

Grade 4

Current School			Dream School		
Feature	Recurrency	Notes	Feature	Recurrency	Notes
Roof	1	red lines going down the roof (maybe the shape of the tin roof)	Multistory building	8	all drawings that we received were multistory buildings, 2-12+ stories high
Plants (maybe grass or tall weeds?)	4	pattern of grass and other plants in red, could	sun	4	
Bugs	3	bugs crawling on side of building	Helicopter pad	4	either a helicopter pad or helicopters flying around. some drawings had multiple
Snake	3	drew snakes crawling on the ground	tall building	8	All
Tree	1		Chimney	1	
Chimney smoke?	2	some of the drawings had chimneys with red smoke coming out of them	Flag	3	thai flag
Rain	2	drew rain clouds and rain falling over the mountains	Lots of people	1	one had many people outside the building
Mountains	1	outline of mountains in red	lots of desks	2	two of the drawings had table/desk looking things
Windows	4	Outlined the window in red, one picture had curtains in red too. some were colored over in red after being drawn in a different color	Multiple buildings	7	most draw more than one building. some of these included houses and some of them even connected
Door	4	Outlined in red	Sports court (basketball?)	1	one drew a sports court that looked like a basketball court, but it could be something else
Pathway	1	dotted the pathway	many classrooms	8	all drawings had

		in red			multiple classrooms in their multistory buildings

Appendix E: Interview Questions

Group	Interview
Students Grades 1-4 (Friday 9-12)	1) Activity a) Ice breaking games (G.1-6) i) Throwing ball game ii) Ninja iii) Etc. b) Drawing pictures of the school i) Picture of school (1) Features they like about their school in one color (2) Features they don't like about their school in red c) Picture of dream school Need: ● Paper ● Markers ● Hard surface for students to draw on 2) Questions/Debrief a) Tell us about what they drew
Students Grades 5-6 (Friday 9-12)	Do you like/enjoy coming to school? Do you think the school building affects how you learn? Why? What about the school building do you like? What about the school building do you not like? What would you like to see in a new building? Do you know what sustainability means? Can you give some examples of sustainability?
Teachers (6)	How does the physical infrastructure affect your teaching? What about the building works well with your teaching? What about the building makes teaching harder? What do you think might help with these problems? What would you like to see in this new building? What's the best use for the new building? (Classroom, cafeteria?)

	What is the most important thing to incorporate in a new school building design? Would you be willing to volunteer in the building and maintenance of the school building? What is your idea of sustainability? (What do you think sustainability means?) What are your attitudes towards the possibility of using waste on the community school buildings? Does culture greatly affect the style of the building? Which features do they affect? Please rank the factor from 1-5 that you believe we should consider when designing the school building? (Culture, Costs, Weather, Functionality, Sustainability, etc) Who is in charge of the school building maintenance?
Parents	Do you feel safe sending your child to the current school building? Do the students complain about the building function and physical state? What would you like to see in this new building? Would you be willing to volunteer in the building and maintenance of the school building? What is your idea of sustainability? (What do you think sustainability means?) What are your attitudes towards the possibility of using waste on the community school buildings? Does culture greatly affect the style of the building? Which features do they affect? Please rank the factor from 1-5 that you believe we should consider when designing the school building? (Culture, Costs, Weather, Functionality, Sustainability, etc)
Farmers (If time allows)	What are common materials in the area? How are these materials being used currently? Could you think of any other ways to use these materials? What materials are used in the building? What are your attitudes towards the possibility of using waste on the community school buildings? Does it seem feasible to use waste or recycled materials on the community school buildings? Would you be willing to volunteer in the building and maintenance of the school

	building?

Appendix F: Transcription of Suppachai Posuwan Interviews

Interview 1

Color Code
Natural Materials
Limitations
Experience with construction
Does not like natural materials

Speaker	**Audio**
Supawan	We are chemists and engineers who don't involve [ourselves] much in the community, so this course will educate us to learn about life conditions. As we associate with Sati, he found one school that need the [helping] hands from us to develop this school either by building new things, or renovating. He just wants to focus on the local materials, but it's not strong enough to stay by itself, so we can adapt in anyway we want to respond [to] the need.
Pam	Uncle Josh, What is the wall made from?
Uncle Josh	It composed of the **Clay and Cement** cover to reduce the smell of the clay because the clay is smelly when it [is] reacted with the humidity, so he used cement to cover the clay surface, and painted it in the natural color.
Pam	How about the roof? It seems you also used the natural materials.
Uncle Josh	It is the **Thatch**, I used it for the roof for many years. If the Thatch is tightly tied, it can stay for 2 years.
Supawan	Is it similar to Japanese roof?
Uncle Josh	Yes, it is. However, the Japanese one is made by thicker level of Thatch.
Supawan	Why don't we do [it] like them? So our Thatch roof can stay longer.
Uncle Josh	It does not need to be that thick because, nowadays, the thatch tee is become lesser.
Supawan	If we do only one layer of Thatch, did it leak when it [was]

	raining?
Uncle Josh	No, it didn't. If it's leaking, we can repair just [the] specific area, so we do not repair all the thatch sheet.
	There are many things in nature that can be used for construction. For example, bamboo, thatch and clay. However, there are many techniques that can make it more sustainable. In the past, the bamboo is not suitable for building a shelter because the insect can consume the sweet part of the bamboo. Nowadays, there is a chemical to bind [it] in the hole of the bamboo to avoid those insects. It [has] worked that way for 20-30 years. I would suggest the clay that does not contain rock in it, which could be called Rammed Earth; it is the combination of clay and cement. This building was 10 years old now. The clay part is still good, [I] don't need to change [it], but the thatched roof needs to change. There is one kind of tree that could be use for [a] building structure, it is called **Gim Soong**. As you know, we can not cut the tree that grows on the restriction area. **Gim Soong bamboo** is best used when it's 4 years old because 2 year old ones contain sweet syrup. The trunk is very strong, and it has a small hollow [hole]. It can [be] used for the roof structure. He bought it from Nakorn Nayok. We can use the hole trunk without any treatment. We can tie up four trunks of bamboo to be one big pole for the structure. However, there is a tree that is able to be cut down legally, which is **TaKruYuk tree.** It can be grown 5-10 years. (This is quite sustainable) Villagers like things that are fast and sustainable. They would rather buy metal, cement, and ceramic tile, but we need to adapt the natural materials to replace [these materials]. The villagers don't know how to make those local materials to be sustainable. Combination of soil with hay! The combination of clay with bamboo will definitely create a house. There is another kind of bamboo called **GaoDao(Nine Stars)**. We can replace that bamboo for the structure and pole of the building.

Interview 2

Color Code
Natural Materials
Construction Considerations
Measurements
Recommendations
Concerns
Building methods

Line	Speaker	Audio
1	**Pam**	This is the Rammed Earth thing.
2	**Maddie**	Do we need to add straw in the mixture?
3	**Josh**	No straw.
4	**Pam**	What about rocks?
5	**Josh**	no big rocks but little rocks are okay.
6	**Lyra**	Where are we gonna get an oven…
7 8 9 10 11 12	**Josh**	For the process, use a can or any square mold, cut the top and the bottom of it. Add about 15 cm of the mixture. Then use anything like a lodge or metal bar to compress it to 5 cm until it is very dense then repeat the process until the height of the wall.
13 14	**McKenna**	if you use fire sometimes with the clay and it's solid so it's like explode. Are there any dangerous?
15 16 17 18 19	**Josh**	you don't need heat, important thing is that dont let them get wet, it will air dry in 2-3 days. Make sure you don't do it in rainy season. You can paint it with lacquer or euritain to make it waterproof.
20 21	**McKenna**	Will the lacquer be dangerous for us? Is this (the wall at the resort) lacquer?
22 23 24 25 26	**Josh**	Yes it is, and no it won't be dangerous, it's like the stuff you used to cover wooden table.[He pulled up example of rammed earth on his phone] If you want the wall to be different colors, you can use different types of soil and you can even add some color to it.
27	**Pam**	What about the roof? Do you have any suggestion?

Josh	If the villagers don’t prefer thatch, maybe you can use ceramic tile or Aluminum depending on the cost. Don’t overthink about the design. Don’t make it too complicated, I recommended 4x8 Meters (right now room is 5x8m) because the metal bar usually is 4 m long, So you don’t have to cut it and add more cost. If you have an architectural engineer friend, they will calculate the cost of everything so it is easier to do the cost analysis E.g. if all of the cost is per day 10,000 baht, we divide it with 300, so we know the number of people who is going to work per day (so we don’t have to ask too many people and waste their time) Then we can estimate the time period it’s going to be done if the building is too big it will exceed our time period, so we have to plan a smaller building
People	*Irrelevant topics*
Lyra	This is the side question but you know if it rains and the electricity goes out, it’s gonna be dark. How often does electricity go out?
Josh	Very often like half a day in rainy season, so it would be July to October.

Appendix G: Transcription of Teachers Interview (School Directors, Mr. Sahud, and Teachers, Ms. Am and Mr. Geng)

Color Code
Natural Materials
Need for a new school
Experience with construction
Does not like natural materials
Children Complaints
Community Willing to help

Speaker	Audio
Jia	Sustainability is our goal, we can either build a new [building] or fix it. I hope everyone gets the idea, that it's low cost and able to live on its own for a long time.
Director	We have laborers (villagers), but you have to give us knowledge/information on how to do it, mixing ratio of clay and cement or anything else we should know to make it "sustainable" because we do not know anything about that.
Jia	Okay, so which building do you think has the worst condition?
Ms. Am	[I] say it is the 3 "can buildings" because they were suppose to be temporary but they have been here for more than 10 years and we don't even know who built them.
Supawan	Let's focus on those "can buildings"
Ms. Am	About the inside of the classroom, would you design a good ventilation(fan), colorful, learning corner as well
Supawan	Students are going to build a model for you to see first.
Director	So you're going to have to be the one who starts building for the villagers to see and finish on their own.
Mr. Geng	I think 3rd grade (room in the middle) needs to be repaired or maybe you can tear it down, we're okay with that.
Ms. Am	We want creative room
Director	You should be able to tell us how many people are going to be needed for one day
Pam	What about the net thingy that isn't a window?
Director	It used to be glass windows and then students play soccer and

	break them so we replace them with net and its good with ventilation in the summer.
Jia	Do you have any concerns about religious belief?
Mr. Geng	You can do anything and culture or beliefs won't be concerned, do it in your way
Directors	I feel like if you're using natural materials, it will be even more expensive than using man-made materials
Pam	**For the conclusion,** The building we are focusing on is the middle of three 'can buildings' (3rd grade classroom) since it is in the worst condition of all of them (e.g. leak roof, unshut door, etc). The literal measurement is 5x8m. Director of the school said that villagers will be willing to help but they don't know anything about sustainability or natural materials [give information], so it is necessary to compute a manual and complete instruction to them. Moreover, after everything is ready, IQP students should to be there when starting the actual classroom building.
Directors	Speaking about clay building, how many days it will take for people to learn how to build it? And preparing for all materials… then those people are going to ask the villagers to help with the building. Building a clay building doesn't finish within 7 days, it takes drying process and whatever...
Geng	I guess you guys already have plan for the whole thing, you just wanna know if anything is missing or if we want anything specifically… right?
Jia	Well, they are engineers and we are chemists, so we're here to focus on the natural materials or any available materials we could use.
Geng	Like, something that's suitable and last long...
Jia	Yes, so we're just observing the area.
Suppawan	inaudible
Jia	So, from what we've been talking is that we're going to be demonstrating/leading how to build then we'll write a manual step by step so the villagers can follow it.
Suppawan	Inaudible… you should be specific and choose one building then take picture of the before and after
Directors	So, it's just one class?

Geng	One class.. Ok but if three is going to be even better lol
Am	You can even use the old structure and maybe modify it
Suppawan	So, about the three buildings, which one is the worst?
Geng	I think 2nd grade building
Am	No, I think 3rd grade has holes, yeah let's go with 3rd grade building.
Geng	The middle one of the three buildings.
Jia	So… build or repair? Is the structure still working all right? If it is maybe we could do both build and repair
McKenna	I think that's something we need to discuss as a group
Directors	You need to tell us, for example, like walls, are you going to change it into clay but still leaving the metal structure and reusing them, you're gonna have to think about those.
Geng	I want a more exciting classroom, i feel like what we have is boring.
Am	Maybe you could build us like a hexagon classroom or whatever haha
Geng	Up to you guys we're just saying
Directors	We're okay with whatever you guys think, like, if you're going to tear the whole bld down or you want to keep some parts. Just design something better, add some fun stuffs to the classroom. Think outside the box.
Geng	Normal classroom would be a rectangle but you can make it differently.
Am	Just save us whiteboard space
Directors	Just consider about the use also. Maybe it could be more than a normal classroom
Pam	Do you know who built that building?
Directors	They're govt. But it's only temporary though, it's a temporary bld which can be demolish
Am	*'Can building'*
Pam	When was it built?
Am	Long time ago. I got here after the school founders left.

Directors	It’s been more than ten years
Teacher	Here used to be a branch of the main school named *Baan Wawee*. There was only one classroom then students will come and study here and then there are many students, so we separated ourselves into another school.
Everyone	inaudible
Pam	Okay, off topic, do you think there will be people who are willing to come and help build the building?
Directors	So, we will invite all the committee members to discuss about your project, then if you provide us with all the materials and tools, I’m sure the villagers will be okay to work. In my thoughts, I think there need to be some educated people here to teach our teachers and then let’s say we will have 5 villagers working each day… (gibberish)

Appendix H: Transcription of Village Committee Interview

Color Code
Livelihood
Natural Materials
Need for a new school
Experience with construction
Does not like natural materials
Children Complaints
Community Willing to help

Line	Speaker	Audio
1	**Jia**	For occupations in the mountains, what do you do for a living?
2	**Village Committee**	Farming corns
3	**Jia**	Do you think the school is good enough now?
4	**Village Committee**	It looks fine, but still some improvements can be made.
5 6 7 8 9	**BSAC**	We are aware that one of the classroom is not suitable for learning at all, so we are suggesting that a new building should be built. However, since we are just university students we need help building the new classroom.
10 11 12 13 14 15	**Village Committee**	Yes, we are able to provide you help with building the classroom.You can get help from villagers in the community, from 100 households. Still, most of the villagers are poor, get paid daily. So an absence from work can affect their income (inconsistent income).
16	**BSAC**	Do the people know construction?
17 18	**Village Committee**	We do, but only on a small scale and we only know how to build structures with wood only.
19 20	**BSAC**	Suppose that there is a hole in your roof, how do you usually repair it?
21 22	**Village Committee**	We don’t fix it, we replace it with the new ones. Our substitutes are handcrafted by us with our guidelines based on past experiences.

	Therefore, the results can be good or bad.
BSAC	Have you heard about mud hut? Or buildings made out of mud/clay?
Village Committee	Yes, we tried to build it but it doesn’t work like we thought it would.
BSAC	What is the most common material for roofs?
Village Committee	Ceramic roofs or tile roofs, which we buy them in the town and transport them back up here.
BSAC	Is there anything that is based on local materials?
Village Committee	Walls are made out of cotton tree trunks and bamboo. They are good as they provide better airflow than other materials. However, it is not as good as cement. Bamboo has a lot of insects that bite into the structure.
BSAC	If we are asking for volunteer workers, would you be involved in this project?
Village Committee	The community is composed of many groups, with each group having 10-20 households. I am one of the many group leaders. The community is composed of 3 tribes living together.
BSAC	Do you agree on us, university students, helping you with the planning and building the school?
Village Committee	Yes, I really appreciate the help from all of you. Also, there is no disagreement among the people regarding the help from young adults.
BSAC	Who built this school?
Village Committee	One of the royal family members gave permission to build the school. She is King Rama IX elder sister. This school is the second branch school, from the main school that is very far away from here. Travelling time takes too long for the children from Chuchi village, which is why another school was built.

BSAC	Are there any complaints about the school from the children when they get back from school?
Village Committee	Just a bit, not that much. Mostly about the cold weather.
Pam	Is there any house that is made out of natural/local materials?
Village Committee	Yes, some are made out of leaves and tall grass (local to us). But they are not that good. For mud houses, we do not recommend since they require skills, specific tools and time.
BSAC	If we provide you with manuals and necessary tools, will you be willing to build the mud house?
Village Committee	If the labor is not that hard, then yes we can do it.
BSAC	We are trying to provide you with solutions that are self-sustainable so that when you guys are on your own, you can do it just by reading the manual. And also we will be providing step by step instructions, so that it will be easy for you to understand and do it on your own.
Village Committee	Most of the houses now are made out of cement, only a few are made out of natural materials. Natural materials are hard to transform into building materials. Furthermore, it is not long lasting; need to be change every 3 to 4 years. Also, we need to treat the materials before it can be used. For example, grass and leaves must be submerged in water and chemicals for a few times to prevent the insects from eating the materials.
BSAC	How do you build the small straw house?
Village Committee	We use redwood and tall grasses as wall and flooring. As for the roof, we used thatched grass that we sew together on our own. Bamboos are not long lasting. Danger to red flour beetles infestation. Thatched grass is hard to find nowadays, we must find replacement.
BSAC	Are there any industries nearby, so that we can use recycled materials?

Village Committee	No there aren't. Still, there are 2 shops nearby that can provide us with suitable building materials.
BSAC	We suggest that the work should be done together as a big group, with proper tools and guidelines.
Village Committee	What are the choices?
BSAC	Using clay and dirt might be troublesome as it is time consuming and also hard to make. We will try using cement or other things to mix with the clay and dirt so that the structure is more sturdy and withstanding. What are the problems mostly for the villagers?
Village Committee	They have little money and no help at all, which mean that they need construction materials, however it is not easy to obtain, don't know where to look, or maybe if they know where to find, the price is expensive. Everyone wants their kids to study in a good school.
Director	We need to do it on our own, and not rely on the government.
Village Committee	I suggest that the villagers should work in shifts, so that the workload can be distributed evenly among the community.
BSAC	What else would the villagers want to know?
Village Committee	Process and timeline.

Appendix I: Transcription of Consultation from the SCG Experience architectural consultant, Mr. Peerapong

Color Code
Construction Considerations
Measurements
Recommendations
Concerns

Line	Speaker	Audio
1 2 3 4 5	**Mr. Peerapong**	First, you need to know what are the Death Load and Life Load. The Death Load is weight of the stuff that can not be moved. The Life load is weight of the stuff that can be move. Things you mainly need to be concerned were structure, cross-section of the steel rods, beam, and safety.
6 7 8	**Jia**	Right now, we have an idea of 5x8 sq.m. area to build one classroom building. It was located on the northern mountain in Chiang Rai.
9	**Mr. Peerapong**	What type of the soil is providing around there?
10	**Jia**	It's orange bumpy road soil.
11 12 13 14 15	**Mr. Peerapong**	It is the mountainous soil, so you do not need the pole stack stick into the ground because this type of soil is strong enough for one 5x8 sq. m classroom building to stand on. Like in some other place, the farming soil will definitely need the stack because the soil will sink down along the time passed.
16	**Jia**	Is there any suggestion on foundation?
17 18 19 20 21 22 23 24 25	**Mr. Peerapong**	For the foundation in previous SCG project, we definitely use the cement foundation because all the natural materials will not support the building 100%, which then it has chance to collapse. There THREE options : 1) Cement+steel rod, 2) Cement+condensed wood, and 3) structural steel. If focusing on the budget, the structural steel is too expensive, and the cheapest one will be cement+condensed wood. Keep in your mind, the suitable materials depends on what activity is that building will be used for.
26 27	**Jia**	How about the structural pole that is usually used to support the body of the building?
28 29	**Mr. Peerapong**	There are also THREE choices: Wood pole, Metal Pole, and cement pole. The decision will be concerned with what is the

30 31		purpose of the building. However, this design should be confirmed by all professional architects or civil engineers.

Appendix J: Transcription of Consultation with the Civil engineer, Mr. Win

Color Code
Natural Materials
Construction Considerations
Measurements
Recommendations
Concerns
Building methods

Speaker	Audio
Win	Can you please tell me the overall details of what this is about?
Jia	The foundation will be made up of concrete and crossing steel rods laying on the earth. The walls will be made out of rammed earth.
Win	Wait, so you guys are going to build the whole thing?
Jia	Yeah, we were briefed that we need to build a new design so that it will replace the old building that they already have. The dimension is 8mx5m. So the new building will be composed of natural materials. The wall will also have bamboo inside the rammed earth block. Our rammed earth block will be made by a compressing machine, that can be manually operated. Additional cement will be poured inside the holes between the block and the bamboo for further reinforcement in the structure.
Josue	Mixture for the rammed earth consisted of 80% soil, 20% cement.
BSAC	The reason why we chose bamboo over steel rods is because we can save a lot of money using local materials
Win	Still, there are some concerns about the bamboo, like its sizes and the inside structures of the bamboo. Also, the bamboo needs to go deep under the ground for about 1-2 meters. Since that will be more durable to winds and rains.

Maddie	Things we need to be concerned about are We have seven weeks to work on this project, and for sure you wouldn’t be able to work for every single hour. Only 60% of a given time will be use to work on this (4 weeks) because we have to do other things too. We should consider every detail/spec of the building - The type of the building - The size of the building For example if we have 100 days to work on this, we can’t do a giant building because we won't be able to finish it. So we need to know the limitation of time and budget which will lead to the limitation of the building quality. So in that 4 weeks time we could use for this project we must know what can be done in this amount of time. So in this 4 weeks, what are we doing exactly?
Jia, Pam, All	We’re designing for the school not building. However, from the previous, project the problem was the villager don't know how to build, even though the manual was provided. It’s like we should start the construction for them.
Win	From what I’ve heard, they want the simplest/ most convenient and least time consuming construction. From listening to the advisor, they want us to use local materials and make it last. The problem is, people here don't understand the new technology that can prolong the natural material. For example : they know how to use clay(attached with bamboo) to make walls and houses but they don’t know how to make it last. For bamboo, it won’t last since it will be eaten by insects , they don’t know how to maintain the bamboo and nmake it last upto 40-50 years. Thatch, will be unusable in 1-2 years, they have it in their village. The point is how can มุง it? This is the thing that you should provide for them.
Lyra	So its like trying to build it in the best way/ the best way to use the material.
Win	We should consider using the local material first before any other options.
Pam	But isn’t cement cheaper?
Win	yes , it is cheaper. But when building the we have to calculate the cost of labor and cost of transportation, thats why it makes the non-local material expensive. So using the local material will eliminate the transportation cost and the labor cost since the villager will perform the work.
Win	The way we do it should be teach the villagers the new

	technology method. For example, your chemistry knowledge would enhance the knowledge of the clay they already have. Rammed earth ratio of 1:4 , use that mixture to build a wall by ramming on it, they walls will looks pretty too. You can give them the information about ratio, how should they do the wood frame (what type of wood, how strong does it has to be and how to leave some spaces for door and windows)
Win	You know the information about this right?
All	No………. We're told them what field are we in.
Win	Do you know anything about the ramming machine
All	Machine? We don't know anything. We can only do statics and some forces
Win	Usually we use metal or wood to ram it, but there is a machine can can do the ramming part. But how can we adjust this machane to fit this project and fit the community needs or can we build other alternative? Instead of buying it from the market.
Mckenna	I would say no but we can research about that
Win	Normally, we can use marinated clay, so it creates the strength and stickiness. But in order for it to last long we should mix a little of cement. It sounds difficult but once we start working on it, its gonna be very straightforward
Pam	How long is it gonna take, the villager said it takes up lots of step.
Win	They did that cause they don't have knowledge, that was the old technique. But for rammed earth its not hard at all. You can try it at home, experiment the 1:4 ratios it can be any DRY soil.

Appendix K: Transcription of Architect from Arsomsilp, Mr.Tana (22/01/18)

Color Code
Natural Materials
Construction Considerations
Measurements
Recommendations
Concerns
Building methods

Line	Speaker	Audio
1 2 3 4 5 6 7	**Thana**	You want to build a bamboo/clay house, is it because it's hard to access on those man-made construction material or is it because they want to cut down the cost? When dealing with natural material by themself, we must know exactly what kind of component we're going to use because for both clay and bamboo house, there are so many different ways we can do. So what do you plan to build?
8	**Proud**	A school building. 5 by 8 single floor classroom building.
9 10 11	**Thana**	Do they have any remained structure? Did they already start building, do they already have the foundation/structure, or are we going to start the whole thing?
12 13 14	**Proud**	They already have their old building but we plan to พัง them down because those building were supposed be temporary but apparently, they've been using it for 20 years.
15	**Thana**	How temporary is it? How is the floor, poles and roof?
16 17	**Jia**	The floor was concrete, galvanized iron roof and the walls was just a plywood.
18	**Thana**	What about poles?
19	**Jia**	A metal pole, it was all rusted.
20	**Safe+Jia**	discussed
21	**Thana**	How many times can you visit the school?
22	**Jia**	We're going for the second visit.
23 24	**Thana**	From what you've plan, how many times you're going to visit the place?

Proud	We went there once, we’re going to go there for the second time soon. We aren’t supposed to be building anything, we just design and send it to our sponsor.
Thana	So the sponsor will build it?
Proud	He will contact and manage the construction process but we have to give him all of the information about what material he should use and how the structure of the building is going to be.
Thana	Who is your sponsor?
Proud	SATI Foundation
Thana	What part are they doing?
Proud	He has done a lot of non-profit social campaign around the northern part of Thailand, he assigned us to design a school building using the local material with the least amount of budget.
Thana	So your job is to design? What field are you in?
Pam	Nothing related to designing.
Thana	oh…. Then, what’s the story behind this project.
Pam	Our professor said chemistry and engineer students usually good in academic and theories, they don't know a lot a practical knowledge. So they gave us a project that we can physically work on, so we learn how to think out of the box.
Thana	Is this like a club, subject or what?
Pam	It’s a subject, we do this for half of the semester.
Thana	They you guys are all from different faculty?
Pam	Yes, our university cooperated on this project.
Thana	How long have you been doing this?
Pam	Almost a month now
Thana	So you have another one month left, the objective was just to design. I don't think that only the design would work because the villager wouldn't be able to understand what to do with it.
	First, he recognize from what you gave me, and I sketch out from my own experiences and guess. Sometimes, it doesn’t work for you guys since I don’t know the roles of how we are going to manage including community’s concern, volunteer

	workers, and my new experience or others.
Proud	We will go to the field again on february,
Thana	So, designing and procedure manual are relating to each other, like if you design them a building, they wouldn't know how to build it, would they? I'm just trying to think about what works best for your goal and all the stakeholders.
Proud	We will be visiting the site for the second times on 5-7 Feb
Jia	Should we talk about what we have got so far? [yes] To make it strong, we work from bottom to top, for foundation, we'll use formwork which is a wooden mold then place steel rods (crisscrossing) and then pour cement. For wall, we want to use rammed earth method compress in the brick compressor...
Thana	There are so many clay buildings techniques. If you use the compressor machine, it's not going to be called 'rammed earth', it's just one of the technique.We'll talk about limitations later.
Jia	Right now, we're concerning about windows and doors on which natural materials should be used. For the roof, we will use the 'TaKuYak' tree which is legal to cut to be the thrust. Then we have the idea of placing bamboos (ซ้อนกัน) and cover it with thatch for another layer.
Thana	Where are you going to do this project?
Jia	Chiang Rai
Thana	You have been in the village, right? Are they still using bamboo for their houses?
Jia	Yes, but people tried to avoid using bamboom because they have change it often and insect are consuming it.
Thana	What type is that hill tribe?
Pam	Rahu
Thana	In thailand, there are still some district that use clay to build their house. However, most of them do not know how to use it correctly even though it is not difficult at all. Even they have a manual of constructing a building, they still always come up with questions during construction or we could say

	that they have no confident in constructing because they are not the one that know or create the project. Therefore, they should not have any problems if we will be the one that lead them anyway.
Thana	As well as Bamboo, it is a traditional usage for local resident. It limitation bamboo also depend on they living activities. Some of them use the bamboo for houses, but their families need to do have a fireplace in middle of the house for their traditional purpose. Fireplace will be used for heat up the meals, so the smoke will be the medium to treat the bamboo to avoid the insect biting. Whenever they stopped using the fireplace, the bamboo won't be suitable enough to use as a wall or for construction at all.
Thana	So nowadays, we use the chemical rather than water.
Proud	Which type of chemical?
Thana	Borax, it's a boron compound, acid. Like boric acid mix with borax, so it's like mix acid and base together so it's neutral
Thana	For bamboo, I don't think it is a good idea to use it at all. They will not fit perfectly and the bamboo neck will make the whole bamboo surface very rough, and can cause water to be stored unintentionally. Thus putting too much weight on the roof unintentionally.
Jia	Maybe we use this as an alternate solution, with the help of other materials?
Thana	Maybe, since natural materials can bend, shrink or expand from different weather conditions. And we cannot know how it is going to plan out.
Proud	So how are we going to build the roof then?
Thana	How will you choose the roof from, what is your criteria?
Proud + Jia	Well, we wanted something cheap and take less time to build, while at the same time durable.
Thana	From my past experiences, natural materials as roofing is not the best way. The reason behind this is because that it is not long lasting
	For instance, there are too many limitations which make the whole idea not applicable. If you want something durable, you use tin, but it absorbs heat and doesn't reflect it away. Furthermore, it can cause health problem. Still, if you want to make the roof a little more long lasting you need to either increase the thickness or the steepness of your roof.

134	**Group**	Inaudible
135 136 137	**Thana**	Oh, why don't you try designing a roof with the mixture of thatch and tin? The bottom layer will be made from tin while the top layer is the thatch.
138	**Pam**	So it will be less cooler than just tin?
139	**Thana**	Yes, but it is not gonna be that appealing.
140 141	**Thana**	Also, tin contains asbestos which can cause cancer when the tin is used after a period of time.
142	**Proud**	What do you mean by that?
143 144	**Thana**	When it is worn out, the dust particles will be produce and inhaling them develops lung cancer
145	**Pam**	But why is it still in use?
146	**Thana**	Because it is very cheap, 22 baht for half a square meter
147 148	**Pam**	Can the bamboo be used instead of steel rods to fill up the hole in the compressed bricks to strengthen the structure?
149	**Thana**	Yes, no problem.
150	**Proud**	Do we need to treat the bamboo?
151 152 153	**Thana**	You should do it. It will be even stronger than usual. Still, the process is very long and if you don't know how to do it the bamboo will rot.
154	**Proud**	What kind of bamboo should we use?
155 156	**Thana**	At least 3-4 years of age. That is when the bamboo is the most sturdy and durable.
157	**Proud**	About the cement column, there should be 4 right?
158	**Thana**	Depending on the structure
159 160 161	**Thana**	About the walls, I recommend you to use the type that is able to withstand the weight of its own. So with the help of the columns it will be much stronger
162	**Safe**	Alright
163 164 165	**Thana**	There is also an alternative for the building blocks. You can also create an adobe blocks from mixing clay, sand and rice husk.

166	**Proud**	So we make them into blocks?
167 168 169	**Thana**	Yes. So you make a formwork that looks like ladder and fill in the mixtures to create brick shapes. When it is dried, the formwork is pulled out and you can use it.
170	**Proud**	How long does it takes for the brick to be dried?
171	**Thana**	7-10 days
172	**Proud**	Is it hard to determine its dimension?
173	**Thana**	It is quite hard to.
174 175 176		A lot of concerns though, since the workers need to know exactly how to do. And the cost to hire the workers are pretty expensive also.
177	**Safe**	So the formwork is necessary.
178	**Thana**	Absolutely
179	**Safe**	How many bricks can be made out of one formwork?
180	**Thana**	Around 4 blocks per each wooden formwork.
181	**Thana**	It's tiring , but not long
182	**Proud**	How long it should take?
183	**Thana**	It's depend on the number of workers
184	**Pam**	We have a lot of people, about 10 people.
185	**Thana**	How about the size of the building?
186	**Pam**	5x8 sq.m. With 3 m. Height.
187	**Thana**	What are the sizes of the window and doors?
188 189	**Pam**	There are two large window on each side(4 windows in total) with size of 1.2x1 sq.m. And 2 doors.
190	**Thana**	Go search video about clay house, just to give you an idea.
191 192	**Proud**	We will mix it by stepping on it, and take it to moldit in the template that have been prepared, right?
193 194	**Thana**	Yes, it will be sticky a bit. Think of baking a bread, it will be similar to that.
195	**Proud**	We have to create our own template, right?

Thana	Yes we need to do that
Proud	We need to do the clay template that contain holes as well
Thana	It's difficult, don't do the hole.
	Interlocking brick will have different ratio from the normal dense one in the way of height if the same length of 10cm. Usually, the interlocking brick will contain 20cm thick.
Proud	Any suggested dimension of the brick?
Thana	Width of 20cm, normally the brick size is 20cm x 40cm and thickness of 10cm.
Proud	So we don't need the pole if we follow this type of method, right?
Thana	Yes, don't need the pole.
Proud	They should be a 4 main structural pole.
Thana	Don't need to have any pole because it actually able to stand by itself.
Proud	How can we arrange the brick and connecting it to make a wall of the building?
Thana	For the glazing material, Just used the same type of clay as the clay brick, it will be a bit liquidus because we add water in the portion. So then later build up the wall neatly and carefully, both for the wall body part and the glazin part used the same type of clay. Basically, the first glazing process will help the wall to stand smoothly. Imagine, if we want it to avoid contact with rain, we can just add the cement into the glazing liquidus clay.
Pam	Can you like, paint the lacquer onto the wall?
Thana	This wall is the wall that allow the humidity in and out.
Group	discussing
Proud	Do you have any suggestion of the ratio?
Thana	I think you shouldn't go deep into details yet. When you gathered a lot of information, you should be able to arrange things out. You just need a basic information finalized out.

	It depends on the rate of working of each worker in shaping the soil brick, so the construction will be fast. For the conditions of rate of 10 people, it should take only five days to finish the work, excluding brick producing; it's only constructing the wall part plus 2 days of glazing, 1 day rest, so it's 8 days total, excluding the roof.
Proud	Therefore, we need to wait until it absolutely dry up, so does it take long to be dried?
Thana	Yes, but after it is dried you can put it directly into use immediately. Still, it is very labour intensive.
Proud	Is the mixture much different from rammed earth mixture?
Thana	Rammed earth is dried earth compressed together, but this one is wet earth and clay molded together in a formwork.
Proud	Which one is stronger?
Thana	They are both of the same strength, but they both need specific calculations and thickness
Thana	But the rammed earth method requires skilled workers. If not, the formwork will not be stable and the rammed earth bricks will be in a very bad shape.
Thana	So if I were you, I would choose the compressed earth brick as main building materials.
Proud	What is this compressed earth brick made out of.
Thana	It is composed of earth and concrete.
Proud	Do we still need to reinforce it with bamboo?
Thana	I am not quite sure, better ask the engineer.
Thana	2.5 m is enough
Proud	Adobe bricks and compressed earth, which is faster?
Thana	Adobe bricks take longer time to dry and it is too labour intensive. While compressed earth is much faster since it doesn't need a long time to try, and one machine only takes a few people to operate.
Proud	For the roof, should we consider building it in double layered style?
Thana	I think you should, the air flow should be better than single layered roof. Since it allows air to escape.

Group	Discussing
McKenna	So, is there a difference in the type of soil you're gonna use? Like this one seem to be like you need a very specific type of soil but this one can you use like any soil?
Thana	What is your specific type of soil?
Proud	So, like this one you use like the dryer soil. This one you use like a...a little bit moist, so like that's why he asked like
McKenna	So you can do the xxx soil for that?
Proud	Yes because Pam and Jia said that there is a river not far from them so we can find that type of soil, if you wanna choose this method.
Jia	How many people are required to operate the compressed earth machine? Since we can't use all of the villagers as they need to work and can only come to help 2 days a week.
Thana	3-4 people per machine. Each are split up to do different tasks. Preparing the mixture, compressing the brick, and taking out the brick.
Proud	Will it be water resistant?
Thana	Since compressed earth has cement content inside, it is water resistant.
Thana	Don't forget the thatch layer for the roof or it will be hot.
McKenna	Do we have to replace the thatch often if it's on the tin?
Thana	Depending on the thickness and how wear-off it looks, we already have tin underneath it anyway. The thicker the better. Make the eaves steep because those are natural materials, they will be decomposed by humidity, mole, etc. So, if we make the roof steep, water will be able to fall down from the roof to the ground quickly, so it will be dried pretty fast. However, if the room's height is not very tall and we make a steep roof, we wouldn't be able to walk into the room.
Maddie	What is the angle?
Thana	I don't know, I don't have a standard, just the steeper the better.
McKenna	How does that change the beam on the inside of the building?

Thana	We will have two sets of beam, one on the top and one on the bottom. Here's what an architect would think, so we got window over here, how long do eaves have to be to be able to block the excess sunlight and rain. So, if the rain comes in diagonally, we can put the eaves in anywhere around here. Or if we want to walk in and out, the roof should be put at least 2 m from the ground. Another thing, how long should the eaves be sticking out from the building? If long, then the wood needs to be thick because it has to bear the weight of the roof, usually it's 1-1.2m.
McKenna	Hotter because
Thana	Because of the material
McKenna	Even if we have thatch roof on top of it?
Thana	Designing is actually to consider all the limitations and choose the best fit for our situation regarding aesthetic as well. In fact, there is no solution that will work out perfectly 100%. Right now we have flatter roof using tin and thatch, the cons are: 1. Thatch will need to be replaced more often or you can make it thicker but that will raise the cost and 2. You cannot drink the rain from it, well, if that is not the case then it's fine.
Proud	I would like to know which ventilation method is the most effective one, cause they said in the summer it's very hot and then in the winter it is very cold.
Thana	Actually, Clay building fits the most in this situation. Well, there are some technical designing but it is a little complex, i mean, architects don't even care about this theory. I'm just saying. So like, Area in the northern part, the sun encircle the south, so people would design a weird shape house like this to get sun but not cold breeze or wind, just sunlight. I'm worried it's going to be over detail. For me, just, in the winter we don't let the wind in and in the summer we have good ventilation system, we'll be good enough. So if the roof is low like this, it's like if the heat gets in it will be near us, maybe lift it up might help a bit or make the end open, so the wind can flow.
	Have you seen the local's house? Sometimes they do like this (talked about picture he drew), they let heat flow out the hole

	in the top roof, at the same time, the roof is able to withstand rain.
Proud	So it’s like, hole?
Thana	Yes, for the villagers, those would be hole.
Pam	Do you think we should go with a double or one layer roof
Thana	Double roof, it’s good with ventilation and give a little extra sunlight but cost more and harder to construct.
	Anything else? If not then that’s it.

Appendix L: Notes from 5th Grade Interview



- New desks - old falling apart
- Cover more in cold weather
- Have projectors that replace the backboard rn
  - Prefer to have the blackboard b/c hard to see on the projector
  - Here for many years and blackboard is easier to take notes
- New book shelf space → each have own shelf on it

- They like the 6th grade room better because of the computer
- Usually move room every year per grade but it depends on the teachers in the room
  - Next year they are going to stay in this room
- Don’t really like posters
- fan→ like ceiling fan better
- Want closed window up under roof → glass windows
- Want swing outside

- In summer really hot → want ac
- This winter weather is cold for them
- Desks are to small → not long table, individual desks better → want cubbie underneath desk
- Floors are cold
- Uniform shoes
- Want new desk for their teacher
- Focus on 4th grade room
    - No windows
    - No fan
- They like science → want to learn more about the science lifestyle poster
- Clean floor
- They want to do experiments
- Cafeteria not clean
- Note: more enclosed space
- Want 2 story building, high level, other schools have 2 story building
- Only school in the village
- High school go outside the village
- Like blue more than green for wall color
- Change window to transparent ones
    - Some say they are okay the way they are

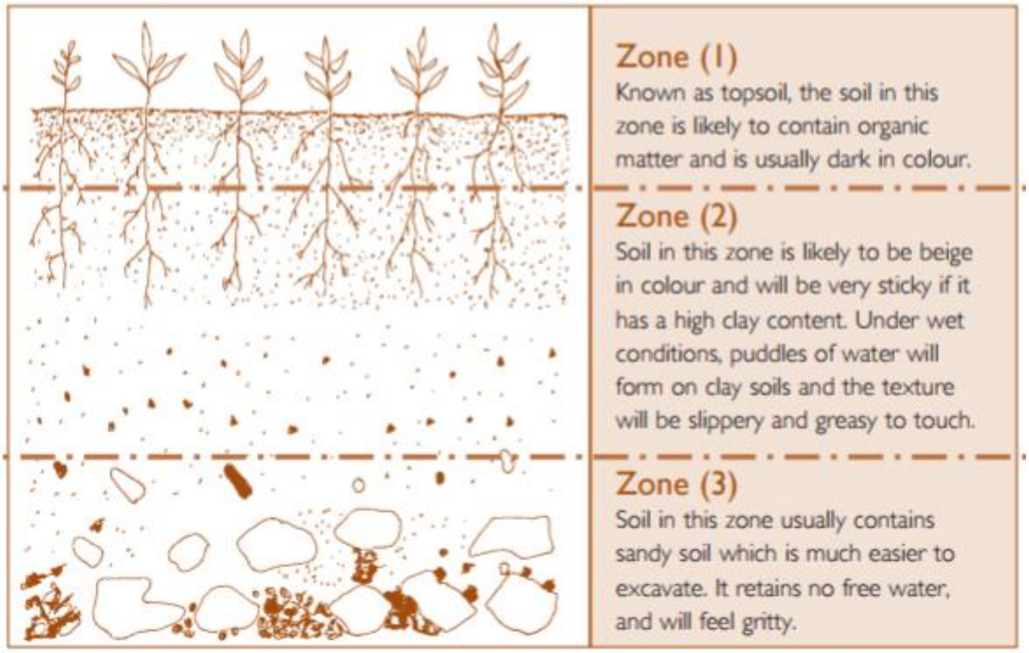
- Want computer in each room
    - Learn on technology more than writing
    - Need for reports, usually hand write reports
    - Like to search experiments videos online
- (the boys left the room halfway through the interview
- (the students are very shy and hard to get the conversation flowing)
- Want to learn music
- (there are 6 female students in the classroom plus the 3 boys that left
- Internet: only teacher has access, no internet in their houses
- (the room is green with tile floors)
- (there's a sink at the front of the room in the desk that does not look like it works)
- (dogs walk in and out of the room)
- Want PE (gym) class to learn badminton and table tennis
    - Right now they just play takraw and soccer
- Want mirror in bathroom
- Children use the bathroom at the bottom of the hill
    - Want a 100% new toilet

- Ages: 13, 12, 11, 14
- (boys entered the classroom again)
- They want all grades at this school 1-9 they usually only finish grade 9 and don't continue after that

Appendix M: Notes from 6th Grade Interview

- They like coming to school
- They like the classroom
    - It is pretty
- Want school to be better
    - Prettier
    - They actually look at the posters
- They like everything
- They have a big cafeteria
- **They hate the dirt**
    - It is not clean
- **Want better bathrooms**
- Too hot in summer, too cold in the winter
- They want to close the windows in winter, teachers want them open
- Want colorful walls
    - Orange walls
- **They go to another school after this**
- Size of classroom: too big
- Cafeteria is not clean
- Would like clay building and leaves as roof
- They like the nature schools
    - Don't like these buildings
- They want to help us build
- They know natural materials are easier to build
- Current buildings are unfeasible
- Parents are farmers (all of them)
- Other buildings
    - Everything is bad
- They like these desks (lecture desks) in 6th grade room

Appendix N: Soil Profile, Testing Procedures, and Results



Soil Test Procedures

Sedimentation Test	Need: glass cylindrical jar (1L, with flat bottom and lid) and 6mm sieve - ⅓ water - ⅓ soil through 6mm sieve - Add teaspoon common salt - Shake well - Sit for 30 min - Shake again 2 min - Sit on flat surface 45 min (until water clears)
Top layer	Silt and clay
Central layer	sand
Bottom layer	gravel
% can be measured by depth of each layer	

Smell Test	smell
Musty	Organic matter, therefore not suitable for building.

Touch Test	Remove largest grains and rub b/w finger and palm
sandy	Rough with no cohesion when moist
silty	Slightly rough and moderately cohesive
clay	Dry:contains lumps or concretions which resist crushing

	Moistened: becomes plastic and sticky

Washing Test	Wash hands after rubbing
sandy	Easily rinsed
silty	Appears powdery and rinse fairly easily
clay	Soapy feel and not rinse easily

Water Retention Test	- Ball fine soil 2-3 cm diameter - Moisten so sticks together but not to fingers - Slightly flatten and hold in extended hand - Vigorously tap water to surface (smooth shiny greasy) - Press b/w thumb and index finger
Fine or coarse silt	Rapid reaction (5-10 taps),flatten ball crumbles
Slight plastic silt or silt clay	Slow rxn (20-30 taps), Flattens not crumbles
High clay content	Slow reaction (30+ taps), flatten ball does not change appearance

Adhesion Test	- Moist ball so not stick to fingers - Insert spatula or knife
Extremely clayey	Penetrates with difficulty, sticks to knife upon withdrawal
Moderately clayey	Penetrates w/o great difficulty, bit of soil in knife
Little clay	Penetrates without resistance, even if spatula dirty

Soil Test Results

Sedimentation Test		
Soil Sample 1	**Soil Sample 2**	**Soil Sample 3**
(without the salt) - 7.2 cm total - rough line b/w silt and clay (~4-5cm) - no gravel or sandy line at the bottom	- Sand and gravel layer on the bottom: 1.7 cm - total soil: 11.9 cm - total soil and water: 12.6 - some organic matter at the top - only small layer of water at the top (compared to how much put in)	- no visible line at all - all silt and clay - no gravel - some organic matter on the water surface level

Smell Test		
1	**2**	**3**
- slightly musty when wet	- little musty smell	- slightly must when wet

Touch Test		
1	**2**	**3**
Dry: - fine chunks broken up into v. fine dust like particles Moistened: - Cohesive with slight roughness - some silty texture	Dry: - Big chunks of dried soil, but can be broken up into fine particles - Small gravel particles throughout Moistened: - Smooth with large rough particles - sticky and plasticy around the large particles	Dry: - Chunks - very little gravel - very fine chunks can be broken but with difficulty Moistened: - very smooth - very smooth with minimal amounts of rough particles

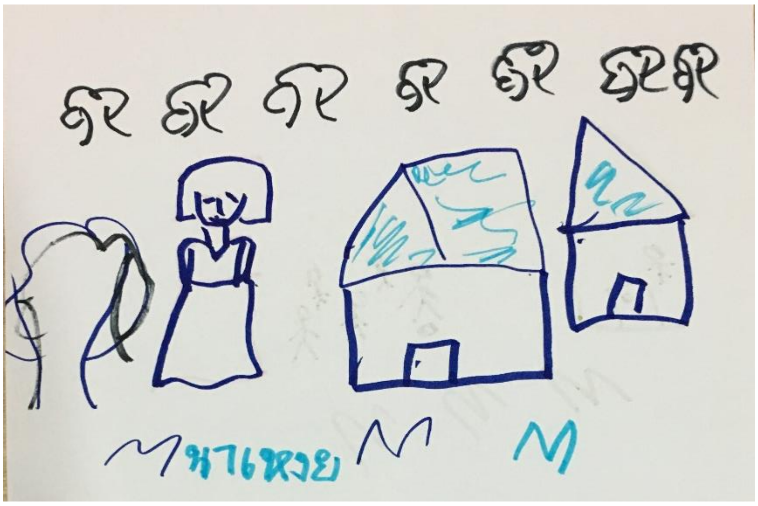
Washing Test		
1	**2**	**3**
- rinses less than easily - stains hands red - powdery	- big gravel wash easily - powdery fell - rinse semi-easily	- rinses less than easily - stains hands red - powdery

Water Retention Test		
1	**2**	**3**
- Smoother, but no reaction to the tapping - got flatter as it was tapped - not greasy or shiny - 30+ taps - crumbles when squished - flattens a tiny bit	- tap vigorously, but to reaction - got smoother, but not greasy or shiny - 30+ taps - flattens	- 30+ taps - no reaction

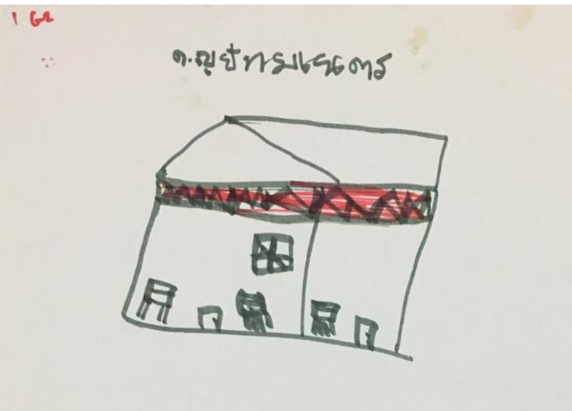
Appendix M: Student Drawings

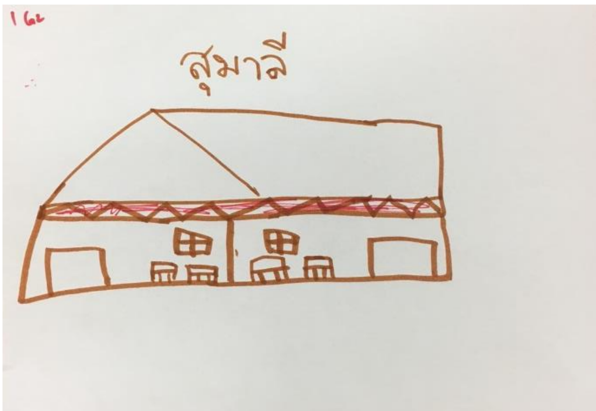
First Grade Dislike

First Grade Dream School



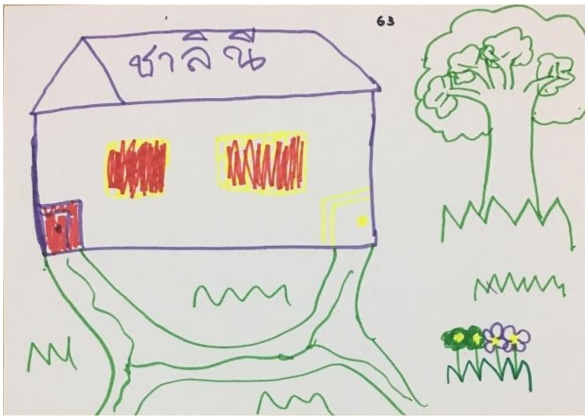
Second Grade Dislike

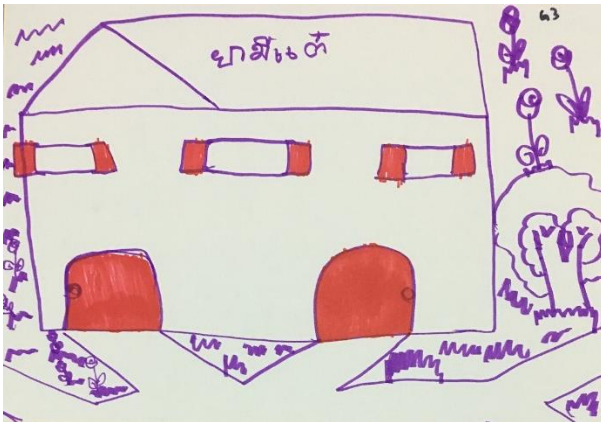




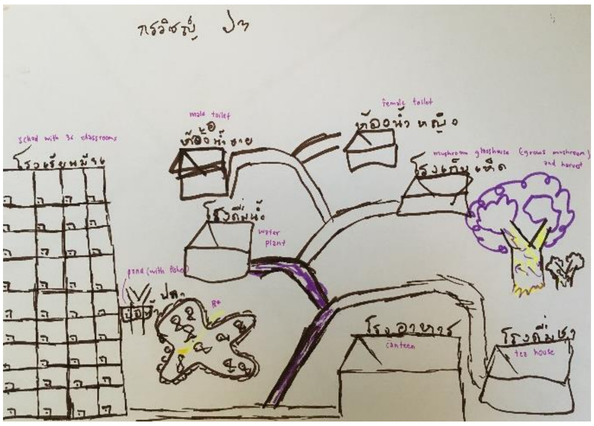
Second Grade Dream School

Third Grade Dislike





Third Grade Dream School



Fourth Grade Dislike

Fourth Grade Dream School