DEVELOPING A COMPREHENSIVE SIDEWALK SYSTEM IN MONTEVERDE, COSTA RICA

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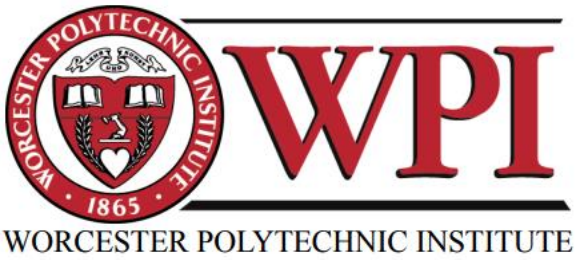

WORCESTER POLYTECHNIC INSTITUTE

Developing a Plan for a Comprehensive Sidewalk System in Monteverde

An Interactive Qualifying Project
submitted to the Faculty of
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ABSTRACT

Monteverde, Costa Rica, is a small community that is lacking a standardized sidewalk system, which can increase the risk of pedestrian-motor accidents. Our team used semi-structured interviews, participant observation, and content analysis to examine this issue. This project provided initial tools to expand coordination efforts across multiple sectors. We executed a town hall with landowners, provided recommendations to the municipality, and designed a landowner manual. Through developing a comprehensive sidewalk system, Monteverde can increase the safety of residents and tourists.

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EXECUTIVE SUMMARY

Sidewalks are important for pedestrians to safely travel to their destinations. They help to alleviate the dangers of walking on a road next to cars and drivers who may not be paying attention to their surroundings. It also gives walkers a dedicated area where they know they will be safe. Sidewalks are an essential safety feature of urban infrastructure in many countries around the world. However, this is not the case in many semi-urban and rural areas. One of these areas is Monteverde, Costa Rica, a small and secluded community in a mountainous region along the continental divide. In Monteverde, people face the challenges of inadequate walking infrastructure and the subsequent danger of walking in roads alongside cars and other motorized vehicles. When there are sidewalks present, they are often in disarray or contain obstacles such as tree roots or large rocks that can pose a danger to pedestrians. These dangers are an unnecessary risk that could be avoided if there were more safe, reliable sidewalks present in the area. Pedestrian safety in Monteverde has increasingly become a public problem in the past decade, as tourism rates in the region have continued to increase and more roads have become paved, leading to an increase in vehicular traffic. Community members agree that a long-term sidewalk infrastructure plan needs to be implemented and that this requires the active participation of landowners, local authorities, and businesses that benefit from tourism. Developing a participatory, comprehensive, and standardized sidewalk system in Monteverde is critical to enhance safety for locals and tourists and decrease road accidents and fatalities involving pedestrians.

The goal of this project was to identify appropriate designs and tools for the development of a participatory sidewalk plan in Monteverde that would comply with current and proposed regulations and that could serve the needs of residents and businesses. Our partnership with Hotel Belmar and CORCLIMA gave us the opportunity to provide the hotel with sidewalk designs that would meet their environmental sustainability standards and integrate their needs with the broader coordination efforts of CORCLIMA, the municipality, and local residents. To reach these goals, we met four objectives. We first determined local opinions related to the existing state of sidewalks in Monteverde. By doing so, we identified what areas of Monteverde had the greatest need for sidewalks and what designs local residents and walkers would prefer. We also identified the sidewalk regulations in place and potential areas for improvement so that any designs we proposed would follow municipal law. We determined what material and installation constraints were present in Monteverde and used these constraints to shape our ideas for sidewalk designs. Finally, we determined how to best inform residents about our sidewalk designs and recommendations and how

to integrate them into a participatory plan. Our team met these objectives by conducting several semi-structured interviews with local residents, including regular meetings with the Monteverde Municipality civil engineer. We complemented this with participant observation and content analysis of meetings and regulations. With the support of our sponsors, we designed and executed a town hall with local landowners and businesses and provided recommendations on regulations to the municipal council.

To consolidate our research, designs, and the information obtained from our interviews and town hall, our team also created a manual that could be distributed to the local landowners to aid them in installing sidewalks on their property. With this manual, we hoped to bring Monteverde one step closer to having safe, reliable sidewalks. We recommend that our sponsor, CORCLIMA, adapt the manual as more needs emerge in order to ensure the manual is up to date and better able to serve the Monteverde community. We also recommend that CORCLIMA and the Monteverde Municipality conduct further research into pedestrian traffic accidents. With the help of the manual and these recommendations, it is our hope that the safety of pedestrians in Monteverde will continue to improve as new and better sidewalks are installed along the most dangerous roads in the area.

1. INTRODUCTION

Sidewalks play a critical role in the safety of pedestrians by keeping them off the street and away from traffic. In general, sidewalks are pathways adjacent to roadways that are designated for pedestrian travel. Without them, individuals become at risk along any roadway. The World Health Organization (WHO), (2013) stated that as of 2013, over 270,000 pedestrians were losing their lives every year while travelling on roads across the world. According to the U.S. Department of Transportation (2019), sidewalks can reduce the number of pedestrians hit by motor vehicles by 71%. The need for sidewalks is a worldwide problem, especially in middle to low income countries. In these countries, 84% of the roads that pedestrians use have no sidewalks (Tulu et al, 2013). The United Nations and WHO's (2017) collaborative road safety initiative (Save LIVES), calls upon government entities around the world to implement core components of road safety including infrastructure design and improvement. The initiative states that sidewalks should be built on every new and existing roadway in order to ensure pedestrian safety. Unfortunately, there is a lack of sidewalks in many developing countries, which can lead to a greater chance of pedestrian injuries (Tulu et al, 2013).

The investment in building a more robust sidewalk infrastructure is critical for the safety of pedestrians. In Costa Rica, a country with relatively limited sidewalk infrastructure, there is an average of over one death per day as a result of road crashes (Alvarado, 2017). For example, there were multiple cases where pedestrians were struck and killed by vehicles on streets that lacked sidewalks (Stanley, 2007). In 2007, a five-year-old girl was struck and killed by a truck in the suburbs of Santa Ana, a community just west of San José, while walking on a street that lacked a sidewalk. In 2013 alone, there were 216 pedestrian deaths and 61 cyclist deaths as a result of traffic accidents in Costa Rica (WHO, 2016). In tourist destinations where pedestrian numbers are increasing, like Monteverde, good sidewalks are critical, but currently inadequate or even absent.

Sidewalks around the world are typically made from concrete due to the fact that it is durable, easily accessible, and economically practical (Thompson, 2018). Concrete sidewalks, however, have come under criticism for their contribution to greenhouse gases in the atmosphere. For every one ton of cement produced, one ton of greenhouse gases are also produced (Mehta, 2001). The world's yearly cement production of 1.6 billion tons of concrete accounts for about 7% of the global loading of carbon dioxide into the atmosphere. Because of this, a sustainable alternative to concrete is being sought. Companies are experimenting with different materials that are more environmentally friendly than concrete. One sustainable alternative to cement sidewalks is a

heterogenous mixture of concrete and other sustainable materials, such as hemp (Peckenham, 2016). Recycled plastic and wood alternatives also have been explored. When designing and implementing sidewalks, many conditions such as geography, weather conditions, locally available materials, budget constraints and the protection of natural resources need to be considered (Indiana Department of Environmental Management, 2007). In addition to this, it is important to take government regulations and pedestrian needs into account when designing a sidewalk.

Environmental impacts of construction have become a point of scrutiny. This includes the materials used for sidewalks themselves, as well as the methods used to install them. Currently, there is very little research regarding the use of environmentally friendly materials to use as an alternative to concrete. Monteverde's Hotel Belmar and the Monteverde-based environmental organization CORCLIMA, seek to identify a type of sidewalk that will satisfy environmental, sociocultural, technical, and financial considerations for use in the area.

Our project goal was to work with our sponsors and local landowners to create an action plan to further develop participatory sidewalk infrastructure in Monteverde, Costa Rica. Our objectives included determining the various material and installation constraints associated with creating a comprehensive sidewalk system for Monteverde and determining the opinions of individuals living in the Monteverde community about the value and importance of sidewalks. We examined current regulations in place in Costa Rica and provided recommendations to Monteverde's municipal council. We executed a town hall with landowners, businesses, and other key community members to share our findings and recommendations and call attention to the need for coordinating efforts. We also created a manual for local landowners that detailed how to install sidewalks that met key objectives such as increased safety and regulations, remaining conscious of sustainability issues, and the infrastructure already in place.

To meet these objectives, we conducted interviews with locals and experts on sidewalk installation in Monteverde. Individuals from the Monteverde Municipality with expertise in sidewalk regulations were a key source of information as they knew what needed to be improved. These interviews along with research into sidewalk installation around the world allowed us to arrive at designs that were suggested to Hotel Belmar. Through our work, we hoped this project has contributed to the ongoing efforts of residents and organizations to improve the sidewalk infrastructure around Monteverde. We aimed to advance road safety in the region and decrease pedestrian related injuries and deaths. In addition, sidewalks can make Monteverde a more attractive and safe destination for tourists and in turn strengthen Monteverde's economy.

2. BACKROUND

Evidence found as early as 2000 B.C.E. in central Anatolia (modern day Turkey) suggests that sidewalks have been a key piece of infrastructure around the world for thousands of years (Agarwal, 2017). Sidewalks have always been implemented with the same purpose in mind: to provide pedestrians a designated area to travel from one place to another safely. Sidewalks can be used to increase pedestrian safety, improve accessibility, and contribute to the overall wellbeing of the community. Despite having a central purpose, different regions utilize different sidewalk designs due to geographical and social constraints. Some are made with concrete slabs and others are no more than dirt footpaths. Recently, however, companies have been experimenting with sidewalk designs that are heavily engineered using ground-breaking materials such as rubber and plastic composites. A multitude of materials have been used to create sidewalks and construction techniques have greatly advanced over the years. This chapter will explain why sidewalks are imperative, discuss what factors must be considered when intending to design one, and give an overview of the current status of sidewalks in Monteverde, Costa Rica.

2.1 The Need for Sidewalks

Sidewalks became prominent in cities around the globe in the early 19th century in order to improve pedestrian travel (Sohail, 2016). Despite the growth in global popularity, there are still regions that lack proper sidewalk infrastructure. Around the world, the lack of sidewalk infrastructure is considered a significant cause of pedestrian deaths. In Kenya, between 1971-1990, pedestrians represented 42% of car crash victims killed with a lack of sidewalks being one of the likely contributors (Azetsop, 2010). The International Road Assessment Programme (iRAP) found that 84% of the roads that pedestrians use in developing countries had no sidewalks (Tulu et al, 2013). Along with these statistics, a study by the University of North Carolina Highway Safety Research Center conducted for the Federal Highway Administration found that once traffic volume and speed limits were taken into account, the likelihood of a site with a paved sidewalk being a crash site is 88.2% lower than a site without a sidewalk (McMahon et al., 2002). These statistics should not be interpreted to mean that sidewalks will reduce crashes by 88.2% but instead be seen as a confirmation of the beneficial effect sidewalks can have on lowering the chances of pedestrian-vehicle crashes. These figures show the extent of the problem worldwide and imply that solutions need to be found.

In Costa Rica, the sidewalks are dilapidated, with random sections that discontinue, large drop offs or step ups, and a lack thereof in some areas (Henfling, 2014). Pedestrians may encounter problems with accessibility and must resort to walking in the muddy streets. This can seriously impact the range of tourists who want to travel to Costa Rica. In addition, the safety of pedestrians is a large concern. With no designated area for foot travel, pedestrians are forced to walk in the road. Due to a combination of narrow roadways, inclement weather, distracted drivers, or other variables, accidents are occurring with sometimes fatal effects. Table 1 shows the most common variables leading to vehicle-pedestrian crashes, both due to the fault of pedestrians and drivers (Doustmohammadi et al., 2018).

Table 1. Primary Contributing Circumstance for Pedestrian Crashes in Alabama (Doustmohammadi et al., 2018, p.71).

Driver's fault	**Pedestrian's fault**
Driving Under the Influence	Improper Crossing
Aggressive Operation	Lying or Sitting in the roadway
Failed to Yield Right of Way	Pedestrian Under the Influence
Not Visible	
Other - No Improper Movement	
Swerved to Avoid Vehicle	
Wrong Side of Road	
Failed to Yield the Right of Way	
Failure to Obey Sign	
Followed too Closely	
Misjudge Stopping Distance	
Traveling Wrong Way	
Unseen Object/Person	
Vision Obstructed	

2.2 Materials and Methods: What Has Been Used Before?

There have been various sidewalk designs utilized around the world. As can be seen in Figures 1 and 2, the City of London (2016) uses paving stone or asphalt as the primary materials in their sidewalks. Portugal uses calçada portuguesa, or Portuguese pavement to create their sidewalks (Beckett, 2019). Calçada portuguesa are stones arranged in patterns that turn their sidewalks into works of art. An example of the calçada portuguesa can be found in Figure 3 below. Despite these

differences in design, it is typical in many places like the United States of America and Costa Rica to use concrete for making sidewalks (U.S. Department of Transportation, 2013; Roberson, 2007).

Figures 1 and 2. Asphalt and stone sidewalks in London, England (City of London, 2016).

Figure 3. Black and white wave calçada from Lisbon, Portugal (Beckett, 2019).

Concrete has been the sidewalk material of choice for decades now, evident through its widespread use around the world (Mendoza et al, 2012). However, there has been much skepticism surrounding this combination of aggregate, water, and cement recently. The process of creating concrete gives off just as much carbon dioxide as the mass of concrete produced, not to mention other greenhouse gases emitted throughout the process (Naik, 2008). Although concrete is very durable, with most sidewalk systems lasting up to 75 years, it can deteriorate over that period of time, resulting in a need for routine upkeep (Berg, 2014). Concrete sidewalk upheaval caused by tree roots, natural factors, and other routine wear results in dangerous and sometimes unmanageable walking conditions.

Recently, companies have been working with cities to come up with solutions to the problems concrete sidewalks cause (Berg, 2014). This is mainly in the form of using new, innovative materials as opposed to concrete. For example, recycled rubber, recycled plastic, and even wood composite sidewalks have their own set of benefits and have gained popularity in recent years (Berg, 2014; Mendoza et al, 2012). The production and installation of these materials have a lower net CO_2 output, overcome issues such as upheaval from tree roots, and provide a use for recycled rubber and plastic.

Recycled rubber tire sidewalks, already produced by companies like TERRECON (2014) (previously Rubbersidewalks, Inc.), are gaining popularity globally for many reasons. Not only do they prove to be cheaper than concrete sidewalks, they also decrease storm water runoff, withstand freeze/thaw cycles, and eliminate the need for tree removal when installing sidewalks (Walking the Walk..., 2009). Rubber is easily accessible due to its widespread use in motorized vehicle tires, which makes recycled rubber feasible for use in creating sidewalks. The United Kingdom company, PAVEGEN, pioneered a rubber sidewalk that is not only sustainably sourced from recycled materials but also converts pedestrian footsteps into kinetic electricity (Berg, 2014; PAVEGEN, 2019). Their products can be found across the world from Dupont Circle in Washington D.C. to Bangkok, Thailand. Their design not only encompasses the initiative of replacing the use of concrete for sidewalks but also generates its own source of green energy. Each footstep on a PAVEGEN sidewalk can generate about 5 watts of power which can be used in environmental sensors, LED screens, or lighting. This power generation also provides data on when and where data is being produced, relating to when and what areas are most frequented by pedestrians. This company shows that sustainability in construction is not limited to what goes into the product, but also what comes out.

Figure 4. PAVEGEN energy absorbing sidewalk (PAVEGEN, 2019).

Wooden sidewalks have been implemented around the world for generations (Pierce, 1930). Wood can be pressure and subsequently chemically treated to prevent rot and insect infestation. Pressure treatments can also increase stability when exposed to certain climates (U.S. Department of Agriculture, 2016). Wood preservation often uses chemicals, and chemical safety can vary depending on the combinations of substances used and the manufacturers, which must be addressed before any sidewalks are installed. Wood is already used around the world for infrastructure such as boardwalks. Hardwoods tend to have a lower maintenance cost, chance of warping, and chance of decay than softer woods and composite decking plastics (PermaTrak, 2019). In addition to this, studies done in Japan found that wood or wood-chip paved walkways have lower net greenhouse gas emissions than other paved sidewalks when kept in place for over two years (Kayo et al, 2015). This takes into consideration the transport of materials, as well as the amount of CO_2 the trees would have consumed had they not been cut down. Regardless of location, wood is an alternative to concrete that has a lower negative environmental impact and also serves other functions such as being aesthetically pleasing as well as easily accessible.

2.3 Conditions to Consider: Environment, Ecology, and Ecosystems

When building any kind of structure, especially sidewalks, there are many conditions that need to be taken into consideration. Geography, topography, weather conditions, and the protection of natural resources are a few of these constraints (Indiana Department of Environmental Management, 2007).

The natural landscape and location of a construction site will determine what can be built. Dense forests and a lack of paved roads in an area may make it impossible to get heavy equipment to a site (Hyde & Watts, 2013). This obstacle, as well as environmental considerations, can make the use of traditional construction methods undesirable or even infeasible in some areas.

Another important factor to consider during construction is the climate of the region. Strong winds, severe rain, hailstorms, hot weather, and an increased risk of inundation can all have an effect on the structures being built (Hyde & Watts, 2013). Careful examination of the climate of the region, and the local history of extreme weather conditions, can reveal opportunities to address constraints brought on by the region's climate.

Once these factors have been considered, there is another significant restriction that needs to be taken into account. Habitat and ecosystem conservation and enhancement can be one of the most important issues that needs to be addressed before and during construction. Maintaining and

enhancing existing habitats is a central issue at sites with endangered or unique flora and fauna present (Hyde & Watts, 2013). In these situations, an inventory of existing species needs to be taken, and the impacts of construction need to be monitored continuously. Addressing this restriction, however, can prove advantageous for some projects. There are many benefits to preserving the environment around a construction site. Indigenous vegetation can slow the velocity of runoff, prevent erosion, and act as a filter to trap sediments and other pollutants from running off into rivers, lakes, and oceans (Indiana Department of Environmental Management, 2007). Vegetation also provides a shield from heavy winds, enhances the visual aesthetics of the area, and allows for wildlife to remain undisturbed. Incorporating the natural features and indigenous plant life of the area into the design can minimize the environmental impact of a structure.

2.4 Government Regulations

Worldwide, sidewalks are regulated and maintained either in the public sector or in the private sector (ADA Solutions, 2019). In many regions, demand is one of the main factors that helps determine if a sidewalk should be installed in the first place. However, other factors such as budget, environmental concerns, and government infrastructure also play an important role.

A recurrent problem regarding sidewalks around the world is that many local governments are not responsible for maintaining them (Evans-Cowley, 2006). Instead, the responsibility falls to the private landowners. Some local governments in the United States such as Seattle, Portland and Boulder will contribute funds towards sidewalks as they have a large population of walkers (Evans-Cowley, 2006). However, these cities have the funds available to do this but not all cities are able to do the same.

In most cities in the United States, the responsibility for maintaining sidewalks is in the hands of landowners (Evans-Cowley, 2006). One specific example of this is the Borough of West Chester, in Pennsylvania, where property owners are responsible for constructing, reconstructing, or repairing a defective sidewalk within 30 days of being notified by the township (Borough of West Chester, 1973). If they fail to do this, they can be fined anywhere from $25 up to $1,000. Another example in the United States is Syracuse, New York, where the landowners are also responsible for ensuring that their sidewalks are clear of snow in the winter (City of Syracuse, 2009).

Although there are places where the governments are legally responsible for the construction and maintenance of sidewalks, there are cases where this is not enforced, such as São Paulo, Brazil (Degreas et al, 2014). Under traffic laws, the government is responsible for sidewalk construction

and maintenance. Despite this, the government pushes this responsibility onto the local landowners. The landowners are then responsible for making sure that the sidewalk conditions are up to standards and that sidewalks are built in the area. This is especially important because approximately 40% of the city is covered in sidewalks.

There are other instances such as in India, where even though the government is responsible for the sidewalks there, they are in such disrepair that people are more willing to risk their lives walking on the roadways than walk on the sidewalks that are there (Das & Goswami, 2018). Although there are laws in place that are meant to protect foot traffic, these do not actually do anything since they are merely taken as suggestions rather than laws. This makes pedestrian travel even more dangerous than it needs to be. As discussed in section 4.2, there are also areas of Monteverde where pedestrians prefer to walk on the road instead of using insecure sidewalks.

In the United States, some of the regulations that exist for sidewalks at the state and federal level come from the Americans with Disabilities Act (ADA Solutions, 2019). These regulations were created so that people with disabilities would be able to fit in with the rest of the society in areas such as public services and transportation, which includes the use of sidewalks. The specific requirements come from the ADA Guide Lines for Building Curbs and from the Title II ADA Regulations. These regulations require that the slope of a curb ramp be 8.33% or less and that these ramps be present anywhere a sidewalk or other pedestrian path meets a curb. Another regulation requires that the width of the sidewalks be 36 inches and that the sidewalk must be level with a street walkway or gutter. Regulations addressing sidewalk accessibility issues have been critical in providing legal guidelines for the design and installation of sidewalks in many areas around the world.

The regulations currently present in Monteverde, Costa Rica, are very scarce. At the national level, Law 4240 from El Instituto Nacional de Vivienda y Urbanismo (2012) says that landowners are required to build and maintain sidewalks. This legal framework also dictates that the maximum sidewalk slope towards the road be no greater than 3% and the material used must be non-slip. If there is vehicular access along the sidewalk, then it cannot disturb the flow of pedestrian traffic. Further guidelines are not included in this law. As in the United States, the laws from El Consejo Nacional de Personas con Discapacidad (The National Council for People with Disabilities) provides requirements regarding access ramps and dimensions (Tribunal Supremo de Elecciones Normativa, 1996). The sidewalks should be at least 1.2 meters wide. The regulatory body also requires a sidewalk height between 15 and 25 centimeters above the adjacent roadway.

Several municipalities in Costa Rica have also further developed their own “Reglamentos de Aceras” (Sidewalk Regulations) (Rojas, 1988, p. 86). They all expand upon article 75 from Law

4240 previously mentioned, which states that landowners are responsible to implement and maintain sidewalks, but there is no timeline on it, and there are no regulations about how the sidewalks should be designed. Analyzing the regulations that exist in Puriscal, San José, and Heredia can offer some insight into the current legal framework for sidewalks in each of these areas (Municipality of Heredia, 2018; Municipality of Puriscal, 2011; Municipality of San José, n.d.). These municipalities are evaluated in Table 2 along with the national laws and the laws that exist in Monteverde in order to see what regulations they do and do not have in common. As can be seen in the table, each of the three municipalities previously mentioned make the landowners responsible for building and maintaining sidewalks in their area. They also all have regulations on building access ramps for people who are disabled. However, only the Municipality of San José mentions anything about railings. These railings are required to have a height of 90 centimeters. Another commonality between all three of the municipalities is that they all recommend using non-slip concrete as their material of choice for building sidewalks. In terms of the minimum width for the sidewalk, Puriscal and Heredia require 1.5 meters, while San José requires 1.2 meters. Something else that is important to consider is that Puriscal and Heredia have explicit time limits written in for when construction must be accomplished, which ensures that people are responsible and complete everything in a timely manner. There are also required height measurements for sidewalks. For Puriscal, there is a minimum height of 14 centimeters. For Heredia there is a minimum of 15 centimeters. Unfortunately, there was nothing available for San José. Lastly, all three of the municipalities charge landowners if the municipality has to do the repairs or installation itself.

Table 2. Comparisons of Costa Rican national sidewalk laws with laws from various municipalities (Instituto Nacional de Vivienda y Urbanismo, 2012; Municipality of Puriscal, 2011; Municipality of San José, n.d.; Municipality of Heredia, 2018; Floribeth Rojas, Monteverde Municipality civil engineer, personal communication, January 28, 2020).

Municipality	National	Puriscal	San José	Heredia	Monteverde
Sidewalk minimum width	Determined by respective Municipality	1.5m	1.2m	1.5m	N/A
Has time limits	No	Yes	No	Yes	N/A

Landowners Responsible	Yes	Yes	Yes	Yes	Yes
Railings	No	No	Yes	No	N/A
Material	Non-slip	Non-slip Concrete	Non-slip Concrete	Non-slip Concrete	N/A
Ramps (for disabled)	Yes	Yes	Yes	Yes	N/A
Sidewalk height from spout	15-25 cm	14 cm	N/A	15 cm	N/A
Vehicular Access	Do not block pedestrian access	Ramps that does not block waterflow	Ramps or removable metal grills	Ramp that does not block waterflow	N/A
Charge owners the cost to build or repair	No	Yes	Yes	Yes	N/A

In addition to lacking a comprehensive legal framework for sidewalk infrastructure, the Municipality of Monteverde also has some challenges regarding political infrastructure and economic resources. Since they are such a small district, they do not actually control their own fiscal budget (Floribeth Rojas, Monteverde Municipality civil engineer, personal communication, January 28, 2020). Their money goes through the Municipality of Puntarenas, which decides which departments in Monteverde receive funds as well as how much money they receive. Due to this, municipal offices in Monteverde are not able to get the economic resources they need for their projects. In addition, they only have one chief engineer in the municipality, and it is her sole job to plan and supervise sidewalk infrastructure in the area. These administrative and budget constraints add important challenges for the Monteverde region.

In summary, there are many places where the responsibility of building and maintaining sidewalk infrastructure falls to the landowners, as is the case in Monteverde. However, there are many areas in Monteverde that lack sidewalks due to a lack of legal framework for sidewalks, limited economic resources, and limited technical expertise. These problems can be resolved if Monteverde

follows in the footsteps of other Costa Rican municipalities and installs the legal framework necessary to establish a sidewalk network and improve the safety of pedestrians.

2.5 The Need for Sidewalks in Monteverde, Costa Rica

Monteverde has a rainy, subtropical climate where humidity, temperature, and rainfall are high year-round (Monteverde Cloud Forest Biological Preserve, 2019). A weather station in Monteverde reported an annual average temperature of 66 °F, with a high of 75 °F in its warmest month of April. The lowest temperature averages at 57 °F in February. Due to the high humidity, Monteverde also experiences a high precipitation rate. The Monteverde weather station reported an annual level of rainfall of 113.9 inches (Climate-Data, 2018).

Such high precipitation rates can lead to flooding, so it is imperative that any sidewalk structure built in this mountainous area drains water properly to keep the conditions on sidewalks safe and prevent damage from erosion. It would be critical that the materials used to build a sidewalk be able to survive the type of climate Monteverde experiences, as well as be safe and durable.

Monteverde is a remote and mountainous area, therefore logistics and transportation of materials and equipment must be carefully considered. A shortage of paved roads makes the delivery of some things inconvenient or even impractical (Cobb, 2017). However, hardwoods such as teakwood, mahogany, and cocobolo are grown in large quantities throughout Costa Rica, making wood a feasible material for the implementation of sidewalk infrastructure (Moss, 1999). However, harvesting timber, especially hardwoods, can lead to greenhouse gas emissions, a loss of biodiversity, changes in water cycles, and marginalization of indigenous peoples, among other issues (World Wildlife Fund, 2020). When a forest cover is removed to harvest timber, wildlife can lose their shelter, food sources, and migration routes severely impacting the biodiversity of the area. When the tree cover of a forest thins, the damp soils of the forest floor heat up and dry out, affecting the forests water cycle. Logging companies continue to reap the benefits of harvesting the forests while marginalizing the indigenous communities who are completely dependent on the forests for survival.

Environmental conservation is incredibly important for Monteverde, which has a very unique and diverse ecosystem. As such, it attracts many tourists each year (Monteverde Travel Guide, 2018). The economy of this region has shifted from being largely dependent on agriculture in the past to having its primary source of revenue be tourism (Amador, 2004). This economic shift towards a tourism-based economy is why conservation has become so important to the people of Monteverde.

Current Monteverde legislation states that property owners are responsible for building and maintaining sidewalks on their property (Stanley, 2007). However, there are no set standards for sidewalk regulations throughout the country. Monteverde law states that property owners are fined if the sidewalk on their property is not maintained properly, but it is unclear how often the sidewalks are inspected, or if this law is truly enforced.

As they exist now, many sidewalks in Monteverde experience issues with drainage, safety, and accessibility. Some examples are shown below.

Figure 5. Sidewalk in Monteverde, Costa Rica, near the Monteverde Institute.

The sidewalk shown in Figure 5 is an example of permeable stone grid pavers that have been used to construct a segment of sidewalk. Although this design allows for easier drainage, the holes in the stone that were previously filled with dirt and gravel have become washed out. This creates a safety hazard, as shoes can get caught in the holes produced, which can lead to tripping. This is especially dangerous for individuals who are elderly or suffer from diseases such as vertigo, as unsure footing is more difficult for them to overcome (T. Leitzke, personal communication, January 22, 2020).

Figure 6. Section where sidewalk is needed in Monteverde, located near the Monteverde Cloud Forest Reserve.

The section of land pictured in Figure 6 is an example of a location that needs a sidewalk, but where it may be difficult to implement. Because the land adjacent to the road is elevated so drastically, it would be impossible to create a sidewalk directly next to the road. Therefore, the sidewalk would have to be constructed atop the land pictured. This creates a safety hazard associated with the drop from the sidewalk to the road and would likely require the installation of a railing to ensure the safety of individuals walking along the pathway. Since the sidewalk would have to be elevated from the road, this creates an accessibility issue: to get to that height, there either needs to be a staircase or a high gradient incline.

Figures 7 and 8. Example of a location where a raised sidewalk has been implemented with alternative stairs.

Figure 7 shows a location near the Cooperative of Artisans Santa Elena Monteverde (CASEM) where old tires have been used to create stairs to an elevated walkway. Although this design uses recycled materials, the tires are not filled fully with dirt or stone, creating unsafe walking

conditions since they compress when stepped on. In addition to this, the trail above is a dirt walkway filled with tree roots, with the surrounding greenery imposing on the path, as can be seen in Figure 8. Although there are many downsides to this sidewalk design, the green space between the walkway and the road is a feature that increases safety, as it gives a separation that could prevent an individual falling from the walkway to the road.

Figure 9. Stone paver sidewalk in downtown Santa Elena.

Figure 9 shows a sidewalk design in downtown Santa Elena that uses stone pavers to create a sidewalk system. As can be seen in the bottom right corner of the photograph above, when cracking or damage occurs, the affected pavers can be replaced easily as opposed to concrete, which when cracked requires the replacement of entire slabs. This design is also wheelchair accessible, non-slip due to the rough surface of the pavers and can be modified to increase drainage.

Figures 10 and 11. Gravel and hardwood pathways in the Salvia Reserve, located near Hotel Belmar.

The sidewalk design seen in the above figures uses a combination of gravel and hardwoods such as cedar. Although hardwoods are more resistant to rot and decay, they still are susceptible to them, especially when in contact with the ground and the high level of moisture that is prevalent in Monteverde (Outdoor Timber Performance, 2014). This design has low environmental impact, is easy to install, and allows for drainage through the pictured grates and channels. That being said, this design can have limited accessibility depending on the size of gravel used, as wheelchairs can sink or get stuck. Due to the heavy rains in the region, it is also possible that the gravel used could wash out quite easily during the rainy season.

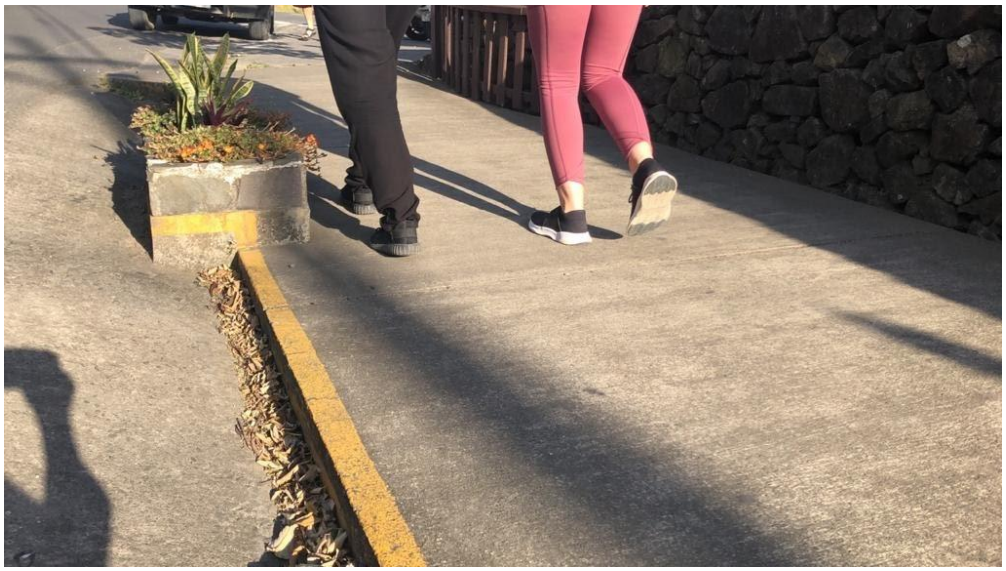


Figure 12. Concrete sidewalk near Poco a Poco, Monteverde.

Figure 12 depicts a sidewalk that was made using concrete. There is a large space between the sidewalk and the road for drainage, which is crucial during the rainy season. The top of the sidewalk is corrugated to prevent slipping. Wheelchairs can also easily travel over it. Only a thin slab of concrete is used, which reduces the environmental impact. However, concrete is still used. This design could be modified to use alternative aggregates, such as glass or fly ash, to further reduce its environmental impact.

CORCLIMA and the Hotel Belmar (Richard Garro & Katy VanDusen, personal communication, October 24, 2019) are both prioritizing environmental protection and conservation considerations to reduce the environmental impact of any sidewalk they develop during and after construction. Hotel Belmar's current sidewalk infrastructure is sustainably built, with minimal impact to the surrounding landscape. However, the individuals living near Hotel Belmar are still responsible for installing their own sidewalks. CORCLIMA has extensive knowledge of the Monteverde

environment, as well as connections to the local population. However, local people lack the engineering expertise necessary to create a comprehensive sidewalk design plan that others could follow and implement. In the next chapter we will discuss how we carried out research to find a suitable solution for building environmentally sustainable sidewalks in a way that considers the needs and resources of local organizations, landowners, and pedestrians.

3. METHODOLOGY

The goal of this project was to identify appropriate designs for sidewalks at Hotel Belmar and surrounding areas in Monteverde that could be introduced through a participatory process and that would conform with local regulations. In order to achieve this goal, we met the following objectives:

1. Determined local opinions related to the existing state of sidewalks in Monteverde;
2. Identified regulations or improvements to regulations pertaining to sidewalk installation for the possible use by the Municipality of Monteverde;
3. Determined material and installation constraints for sidewalk designs for Hotel Belmar and surrounding areas;
4. Determined how best to inform the local people on the benefits of sidewalks and sidewalk design options;

In this chapter, we discuss the methods that we used to achieve the outlined objectives and thus our overarching goal.

3.1 Determined Local Opinions Related to the Existing State of Sidewalks

Locals and people who walk frequently around Monteverde are the ones who will be building and maintaining any sidewalks, so it was imperative that their opinions, ideas, and preferences were considered when designing new sidewalks.

3.1.1 Interview Individuals Living Locally

When building any type of structure, it is important to get feedback from the people who will be affected by it. To assess local opinions on the goal of the project, we conducted semi-structured interviews asking the locals about their thoughts regarding the need for sidewalks in Monteverde and what suggestions they had for the design of the sidewalks. Since English and Spanish are two of the most prevalent languages spoken by the residents of Monteverde, the interview questions were available in both languages. The English and Spanish versions of the interview questions can be found in Appendix A.

All the individuals interviewed were identified by our CORCLIMA liaison as integral members of the community who walk frequently around Monteverde or have knowledge pertaining to our project. Some of these people have disabilities that make it more difficult for them to walk on dilapidated sidewalks, while many have encountered times when they have been injured or know

someone who has been. We interviewed equal numbers of native Costa Rican residents and foreigners who moved to Costa Rica over five years ago; in total 10 individuals.

3.2 Identified Regulations Pertaining to Sidewalks for the Municipality

Before any sidewalks could be designed, we had to determine whether there were any laws or regulations already in place in Monteverde with regards to sidewalk installation. In order to do this, our team met with Floribeth Rojas, the head civil engineer at the Monteverde Municipality, once a week for six weeks in order to understand current regulations and what improvements to these regulations would benefit the area. These meetings informed us about what the municipality is and is not responsible for and what responsibilities fall on the landowners. Regulations from several other municipalities in Costa Rica were studied online and through interviews in order to see what practices have been implemented in other areas. This gave us insight into what could possibly be implemented in Monteverde. By consulting the legislation already in place, as well as speaking to 10 locals with experience building sidewalks, frequent walkers, and disabled individuals, we were able to determine what needed to be included in the new legislation. Once a range of data related to sidewalk regulations had been collected, our team brought our proposed regulations to the Monteverde Municipality for their review, comments, and criticisms. These findings and recommendations were formally presented to Monteverde's municipal council by our sponsor Katy VanDusen on February 25, 2020.

By conducting regular meetings with Floribeth Rojas and consulting with the municipal council, our team ensured that our suggestions would be appropriate and acceptable to the local authorities.

3.3 Determined Material and Installation Constraints to Create Sidewalk Designs for Hotel Belmar

As it stood at the beginning of our project, there were no safe walkways on the road leading up to the Hotel Belmar. This put any of the hotel's guests, as well as the residents living along the roadway who prefer to walk to their destinations in a precarious and dangerous position. To address this concern, multiple designs were created in order to provide the hotel with a plan to implement a safe, environmentally friendly sidewalk that they could build. This contribution to the community was the first step in a larger plan to implement the designs provided by our team. To create these designs, multiple conditions and constraints had to be considered. We conducted research related to

weather, environmental, and geographic features in Monteverde, as they limited the types of materials and designs that could be used. Once these conditions were considered, we created multiple designs that the hotel and CORCLIMA could use to achieve their desired goals.

3.3.1 Developed Designs for Sidewalks at Hotel Belmar

Before presenting designs to Hotel Belmar and CORCLIMA, many factors were taken into consideration including environmental concerns, as well as appearance and the availability of materials in the area. Materials considered for the sidewalk included recycled plastics, wood composites, alternative concrete aggregates, and gravel, among others. Repair and maintenance requirements for each of the materials was considered in an effort to lessen long term maintenance costs. We also walked on the sidewalks located throughout Monteverde to see what locals contend with on a daily basis. The pros and cons of these sidewalk designs were explored through our interviews in order to choose the best design to implement at the Hotel Belmar.

It was crucial that we inspected the possible areas for installation of a sidewalk at the hotel. Pitch, ground type (i.e. grass, sand, dirt, etc.), and an available area for installation are all aspects that could impact what types of materials could be used, and how to proceed with the installation. We physically inspected and took photographs to document all areas in which sidewalks were to be installed at Hotel Belmar. Our team used a tape measure to determine the available area between the road and the adjacent hibiscus bushes that marked the edge of the current footpath. Pitch was measured by the hotel maintenance crew. Through meetings with our liaison at Hotel Belmar and other key employees, we got a sense of what materials they were and were not willing to use. The hotel cited materials they had used before and were feasible to obtain such as wood composites, gravel, and cedar wood.

In a location such as Monteverde where the environment is a focal point in the appeal of the town, it was important to make sure that the sidewalk design did not distract from the natural appearance of the landscape, blended in as seamlessly as possible, and had low environmental impact. Monteverde's rural landscape and greenery attracts tourists from all over the world and is a characteristic of the town that could be lost if there were an increase in urbanization and the installation of infrastructure (Katy VanDusen, CORCLIMA Coordinator, personal communication, January 28, 2020). In order to determine what makes for a distraction to the landscape, we walked the sidewalks around Monteverde and Santa Elena, contemplated, and photographed the various types of sidewalks and pedestrian situations. Finally, meetings were set up with our liaison at Hotel

Belmar to discuss the hotel's main concerns regarding sustainability. Since Hotel Belmar is an environmentally conscious business that emphasizes sustainability in all its initiatives, it was imperative to take the preservation of the natural environment into account.

Sidewalks from all around the world were researched, but sidewalks in the United States were used as a primary reference. This is due to the fact that there are very specific guidelines for U.S. sidewalks that can be found online, including the materials used, methods of installation, and pros and cons of different designs. In addition to this, sidewalks in the U.S. are proven to be effective and durable through their widespread use; they are well-designed and consistent across the nation. Many online resources were used, such as different township's Department of Transportation (DOT) websites. DOT websites often have specific designs that can be followed to install concrete sidewalks in particular, as well as drainage and curbs. In particular, the City of San Diego, California, and Clark County, Washington, were used for reference. For alternative sidewalk designs such as pavers and gravel, our research followed the ideas and practices of companies that install and design sidewalks of similar type. Our research allowed us to narrow down designs that could work best for the climate and landscape in Monteverde.

3.4 Informed Locals of the Benefits of Sidewalk Installation and Determined Their Concerns

It was essential to provide locals with a platform where they could voice their opinions and concerns, in order to ensure that the community's best interests were being met when we proposed a plan for a comprehensive sidewalk system. It was also important to inform the locals of what current regulations expect of them, as well as ensure they were aware that this project involved the entire community. To do this, we conducted a town hall meeting held at the Hotel Belmar on February 26, 2020, and a target audience was invited. Attendees included the landowners between the hotel and the gas station located at the junction of the main road and the road leading to Hotel Belmar. Also in attendance was the civil engineer from the municipality and a local constrained to a wheelchair.

The town hall began with a presentation discussing the importance of sidewalks and the various sidewalk designs that could be implemented by the landowners along the road from the Hotel Belmar to the gas station. The presentation was conducted in English with simultaneous translation provided by Katy VanDusen. Following the presentation, Katy and our team facilitated a discussion between the attendants where they raised their concerns and shared their ideas about building sidewalks on their property. This meeting allowed for a direct and streamlined approach to gather

feedback on different designs and implementation concerns. The meeting also served as an inaugural moment to coordinate future efforts between local businesses and residents. In the following chapter, we will be discussing the results obtained through carrying out the methods we have outlined in this chapter.

4. RESULTS AND ANALYSIS

After concluding interviews and research, our team was able to determine local opinions on sidewalks, identify what aspects of Monteverde Municipal law needed to be improved, determine material and installation constraints around Monteverde, and how to best inform locals of the benefits of sidewalks. This allowed us to take one more step towards achieving our goal of creating a participatory plan for the installation of sidewalks around the Monteverde community. In this chapter, we will be explaining what we found when we achieved our objectives, and the analysis of our findings.

4.1 Determined Local Opinions Related to the Existing State of Sidewalks in Monteverde

Based on interviews with residents, we found that many of them had similar opinions regarding what types of sidewalk designs they liked, as well as what designs they found to be the worst. Almost all of the 10 people we interviewed stated that their favorite sidewalks were ones made of gravel, as seen in Figures 10 and 11, as they blend seamlessly into the surrounding environment and do not detract from the natural landscape of the areas neighboring the sidewalk. The interviewees also mentioned their least favorite sidewalk type. They felt that the permeable stone grid pavers, as seen in Figure 9, were the worst sidewalk design in Monteverde. As part of the design, the permeable stone grid pavers have a series of recesses filled with gravel or dirt. During the rainy seasons in Monteverde, that gravel or dirt gets washed away, making it possible for pedestrians to get their feet caught in the recesses, potentially causing them to trip and fall.

The interviewees were asked what characteristics they would like to see in a sidewalk implementation. Many of them expressed a desire to have some separation between the sidewalk and the roads. They believed that having a green space between the road and walkway would provide pedestrians with more safety as it would add a barrier between cars and walkers. They also suggested adding some native foliage in this green space to add more protection and also make the walk more pleasant and beautiful, as seen in Figures 13 and 14.

Figure 13 and 14. Examples of the inclusion of a green space near Hotel Belmar.

Each person interviewed provided us with similar guidance on how to approach landowners. Since Monteverde is a small, close-knit community, interviewees suggested that sidewalk development be promoted as a community improvement plan that would be completed by members of the community. If landowners were directly involved in the project and felt like their ideas and input were being considered, they would be more likely to want to participate. However, the interviewees also shared with us reasons why landowners have been hesitant to install sidewalks in the past. They said that landowners may not have the personal funds, access to machinery, or prior construction experience required to build a sidewalk. This information was crucial, as it allowed us to better understand how we could further help the local population and frame our proposal in a way that did not intimidate them and took their concerns into consideration. Appendix A includes the transcript of interview questions asked to each individual.

The information acquired during these interviews was essential in developing our designs for the Hotel Belmar and the manual. Each of the design options presented to the hotel included a green space separating the sidewalk from the road and the possible use of native plants in this space to add an additional barrier. It became apparent through interviews that the locals' favorite sidewalk design consisted of gravel with wood siding. We also utilized their advice on how to approach landowners. When creating the manual discussed in section 4.5, we made sure to include an introductory page describing the plan as a community improvement project whose success depends on the collaboration of the whole community. To ensure we produced a safe and reliable sidewalk, we researched and suggested improvements to the municipality's regulations for sidewalks in conjunction with Floribeth Rojas, the municipality's civil engineer.

4.2 Identified New Regulations Pertaining to Sidewalk Installation for the Municipality Council

In order to address the variability of the sidewalks in the area and to promote consistency, we decided to create more definitive rules on sidewalk design and construction. As per municipal law, the responsibility of installation and maintenance falls on the local property owner (Rojas, 1988, p. 86). Outside of this regulation, little had been established regarding the continuity, dimensions, and the slope of sidewalks throughout the town. As a result of sidewalks being the landowner's responsibility, it is very common for multiple designs to exist in one area. Steep slopes and the use of potentially slippery materials can make travel on some sections very dangerous, especially for individuals that require the use of mobility devices such as wheelchairs. In addition to this, obstacles and muddy conditions in walkways may lead pedestrians to walk in the roadway, which is also unsafe. In other areas, sidewalks do not even exist at all.

Despite a lack of standard regulations, the municipality has some general guidelines it has followed when constructing sidewalks previously (Floribeth Rojas, Monteverde Municipality civil engineer, personal communication, January 28, 2020). Such guidelines include the slope of the sidewalk, which must be a 2% decline towards the street to allow for water drainage, the width of the sidewalk, which must be between 1.2 and 1.5 meters to allow for wheelchair access, and the elevation of the sidewalk, which must be at least 20 centimeters above the road scaling up to 70 centimeters. We drafted two more guidelines that stated that the sidewalks should be parallel with the road, with a gradual incline and decline, as well as that the sidewalk must be continuous from an adjacent sidewalk, if one exists, to the next. The final guideline states that the material must be non-slip. Although this was mostly discussed with Floribeth Rojas, the three municipalities that we researched all included these constraints in some form or another (Municipality of Heredia, 2018; Municipality of Puriscal, 2011; Municipality of San José, n.d.).

In addition to these sidewalk constraints, there were some other regulations we felt would be important to include. The first of these was identifying when a sidewalk would require a railing and how it would be built. We decided that railings would be required whenever the height of the sidewalk exceeded 70 centimeters above the road, the slope of the sidewalk exceeded 6% or there was a steep drop-off on one side of the sidewalk. In addition to this, we decided it would be important to get special permission if the height of the sidewalk exceeded 70 centimeters above the road. This was decided in consultation with Floribeth Rojas, the Municipality's civil engineer, as well as drawing inspiration from the regulations set forth for San José, Costa Rica.

The third part of the regulations established a timeline that landowners would be expected to follow. We decided that the landowners would have two years to implement sidewalks along public roads once these regulations had been announced, or two years after they move in following the implementation of these laws. If the landowners failed to accomplish this task, then the Municipality would install the sidewalk for them, but the landowner would be charged for everything that it cost to install the sidewalk, including materials and labor. We came to these conclusions when reading the regulations that existed in Puriscal as well as in Heredia (Municipality of Puriscal, 2011; Municipality of Heredia, 2018).

Once we finalized our suggestions, they were given to CORCLIMA and Floribeth Rojas for a final review. The proposed regulations were presented by our CORCLIMA liaison, Katy VanDusen, to the Monteverde Municipality Council on February 25th, 2020 at 4:45pm. Allocated a 15-minute period, Katy spent five minutes presenting the regulations, followed by a 10-minute discussion. The council discussed different concerns over the responsibility of sidewalk installation. The main point of scrutiny was that in the past, the municipality has assisted some landowners with the installation of sidewalks sporadically around town. One council member voiced his opinion that it would be unfair to now expect all landowners to pay for their own implementation when the council had previously paid for and assisted others. Another area of deliberation was how to enforce reimbursement to the municipality in the event that the landowner failed to comply with the implementation timeline, compelling the municipality to install the sidewalk themselves. An additional aspect considered was how to establish who is responsible for installing a sidewalk with respect to cases in which they can only be installed on one side of the road. In these scenarios, neighbors on both sides of the street would benefit from the implementation of the sidewalk, even though only one side would be responsible for giving up part of their property, paying for installation, and the actual implementation itself. The council discussed possible collaboration between neighbors but questioned once again how it would be enforced. Although many aspects of the improvements were deliberated, the council decided to begin the process of amending the existing regulations to include the new suggestions proposed by our team. The full list of regulations proposed can be found in Appendix B.

4.3 Determined Multiple Sidewalk Designs for Hotel Belmar to Use as a Prototype

After assessing the location where the prototype sidewalk would be built by Hotel Belmar, we drafted three designs, taking into consideration the constraints of the landscape. Due to frequent heavy rains, the material chosen needed to be slip resistant as well as remain stationary despite

shifting soil. It was also important to ensure that the sidewalk would conform to the diverse topography of the region. This included the various inclines and declines of the area since there are plenty of areas where steep sections exist. There were also some sharp turns where a sidewalk would be useful to prevent potential pedestrian accidents. The information acquired during the interviews with the locals was essential in developing our designs for the Hotel Belmar. It became apparent through interviews that the locals' favorite sidewalk design consisted of gravel with wood siding. The designs we created after taking these considerations into account were presented to Hotel Belmar and they then decided which option best suited their needs. Following their decision, the hotel agreed to build a prototype on the edge of their grounds, prior to the next landowner's property. The design options are pictured below.

4.3.1 Design One


Figures 15 and 16. Design option with gravel and wood siding, with metal grates for drainage

Figures 15 and 16 show our first design option, which utilized gravel and a wood-plastic composite siding. Gravel was suggested due to the fact that it prevents slipping, is easy to obtain locally, economically viable, and does not detract heavily from the surrounding environment. Wood-plastic composites were suggested because they had been used by Hotel Belmar before, as well as other locations around Monteverde, so it was easy to find where they could be obtained. In addition to this, the composites hold up against rot and insect infestation better than regular hardwood. PVC pipes that connected and drained out to a gutter adjacent to the sidewalk were suggested. A metal grate with holes smaller than the average size of gravel in the sidewalk could be placed over the PVC pipe to prevent gravel clogging the drainage. The negative aspects of a gravel walkway design include potential wash out due to heavy rains, as well as limited accessibility for individuals requiring the use of a wheelchair or other mobility devices. In addition to this, the plastic in the wood

composite is at risk of deteriorating, and subsequently leaching microplastics into the water supply (Aaron Sakulich, WPI civil engineering professor, personal communication, November 18, 2019).

4.3.2 Design Two

The second design option utilized concrete with sustainable aggregates. Although concrete in and of itself is not the most environmentally friendly material, working with alternative aggregates, such as recycled glass, rubber, or agricultural waste reduces the greenhouse gas emission greatly. It is important to understand with any aggregate material using significantly more coarse aggregate than fine aggregate will increase permeability but decrease the strength. Conversely, if more fine aggregate is used, the strength will increase, and the permeability will decrease. Therefore, the ratio of coarse to fine aggregate in any concrete application must be considered, and often experimented with.

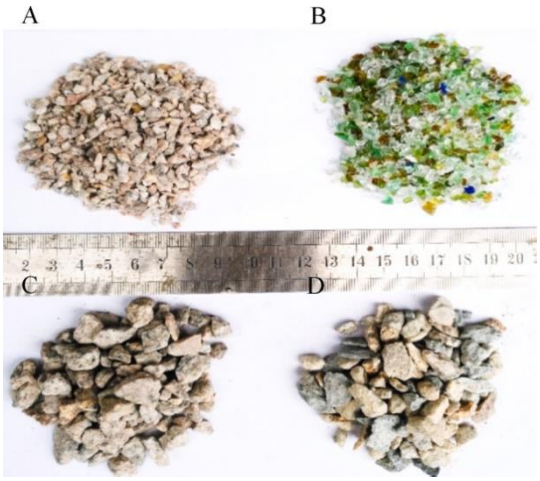


Figure 17. Size differences between fine (above) and coarse (below) aggregates (Chandratilake, 2012)

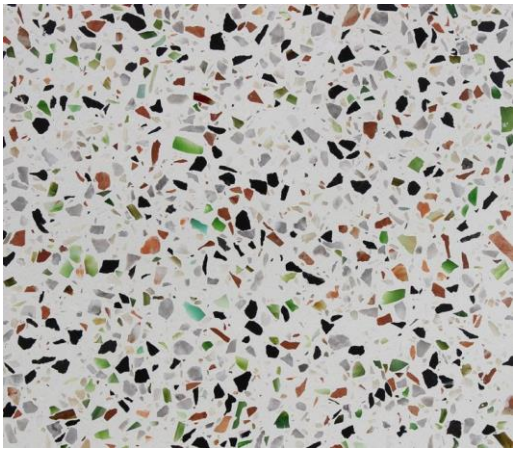


Figure 18. Recycled glass used for aggregate in concrete (Recycled Glass…, n.d.)

Using recycled glass greatly increases durability factors of concrete, such as denser microstructure and better absorption, which ultimately leads to greater strength over time (Nassar, 2012). Additives such as powdered silica fume can also be added to further increase the strength (He et al, 2019). Research has found that a 10-25% replacement rate of aggregate with glass is ideal, although this depends on whether the glass will be used as fine or coarse aggregate. Figure 17 above shows glass that was used for fine aggregate, sized between 2.36-5 millimeters. Figure 18 shows an example of concrete that used glass as a coarse aggregate.

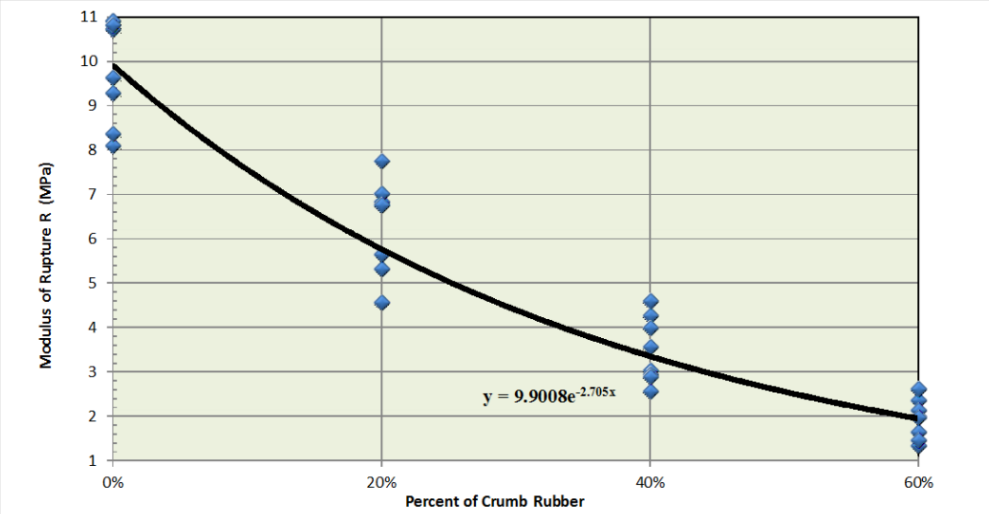


Figure 19. Modulus of rupture related to percentage of crumb rubber in concrete design (Bani-Hani, 2015)

Recycled crumb rubber from motor vehicle tires serves to decrease the weight, but also decreases the compressive and flexural strength, as seen in Figure 19. With this in mind, a 20% substitution rate was the most ideal for a rubber aggregate sidewalk.

Figure 20. Sizing of coconut shell sections used to create sidewalk section (Shafigh et al, 2014)

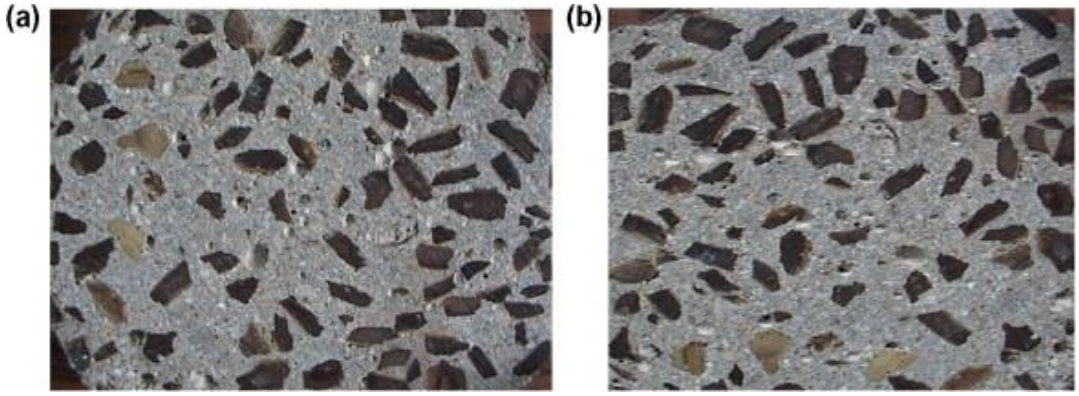


Figure 21. Coconut shells used as coarse aggregate in a concrete sidewalk (Shafigh et al, 2014)

Agricultural waste, such as coconut shells, are also an aggregate that can be used to create durable light-weight concrete (Shafigh et al, 2014). Additional studies found that coconut shell aggregate had higher water absorption rates, developed more compressive strength over time, and resisted biological decay over a one-year study period (Gunasekaran et al, 2012). Overall, compressive strength of concrete decreases as the percentage of coconut shell in the mixture increases (Sonawane & Chitte, 2016). Although there are benefits to using coconut shell as aggregate, the longest study performed so far has only been a year long. Biological decay may occur, causing the sidewalk to decay and become unusable unless replaced.

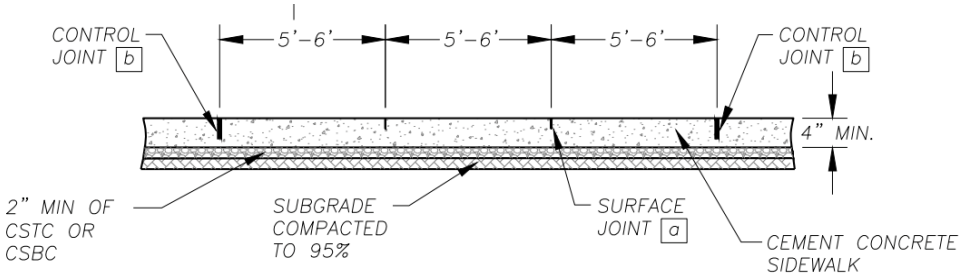


Figure 22. Basic installation requirements of a concrete sidewalk (Government of Clark County, 2019)


Figure 23. Example of crushed surfacing top course (Construction, n.d.)

Figure 22 shows the basic installation specifications to follow for any sidewalk design, beginning with a 2-inch layer of compacted subgrade soil. Following the subgrade soil is a 2-inch layer of crushed surfacing top course (CSTC), as seen in Figure 23. Finally comes a 4-inch minimum layer of concrete. It is important that the final layer of concrete includes surface joints, as Monteverde is prone to soil erosion and natural disasters such as earthquakes, which could lead concrete to crack if placed too close together.

4.3.3 Design Three

Figure 24 shows our third design option, which is constructed with the use of pre-cut stone or concrete pavers. Stone is easy to access around Monteverde, and simple to install. This sidewalk can be designed to be permeable, as in Figure 25, so it won't flood during the rainy season, and slip resistant. In addition to this, this sidewalk is easy to fix in the case of damage, as individual stone panels can be removed and replaced. This design also detracts less from the natural environment than standard concrete.

Figure 24. An example of stone paver application

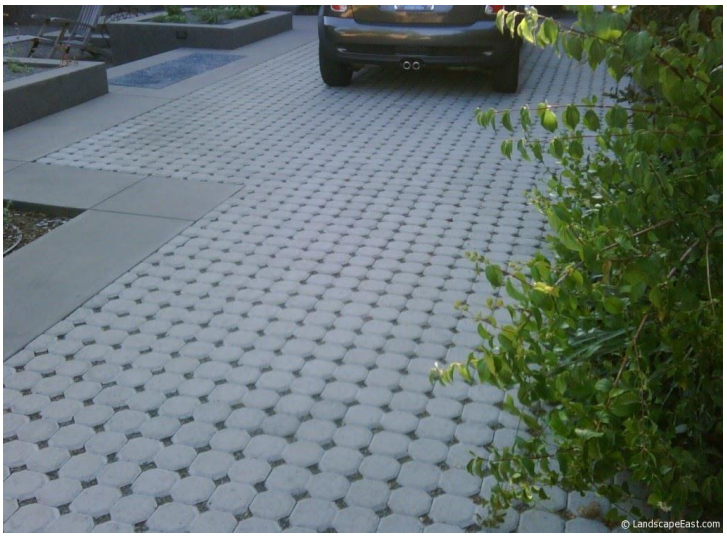


Figure 25. Example of stone pavers with space for water permeation (Stewart, 2017)

Stone and concrete pavers can be installed any number of ways, for example the method displayed in Figure 26. This installation design includes a woven underlay, used when the soil is clay, silt, or any other type that is susceptible to poor drainage. In addition to this, it needs a compacted subgrade, the same as in concrete sidewalk designs.

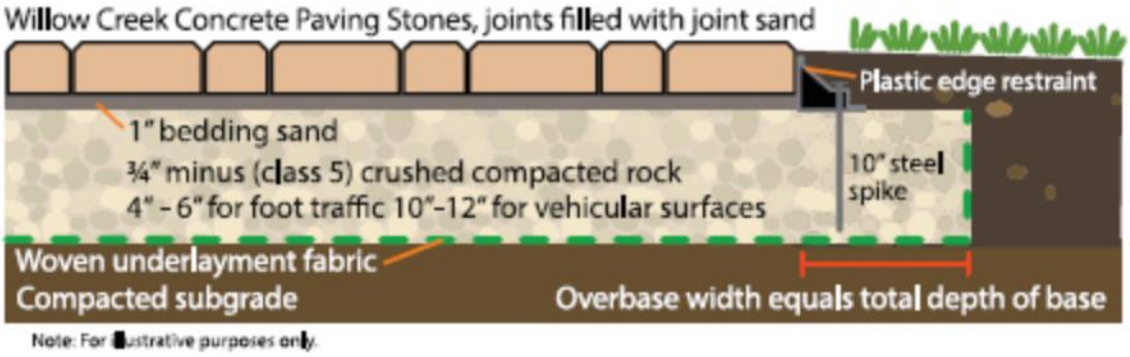


Figure 26. Example of an installation method for stone pavers (Willow Creek, n.d.)

4.3.4 Final Thoughts and Design Decision

For every design constructed, the inclusion of a green space separating the sidewalk from the road was suggested. The inclusion of a green space that is at least .5 meter wide increases the safety of pedestrians, their connection with the landscape, and the natural feel of the sidewalk. Designs two and three were designed with a 2% gradient towards the road to allow for drainage off the sidewalk. Terrace ditch gutters were suggested for drainage adjacent to all sidewalk designs to allow for further watershed down the road, as seen in Figure 27.

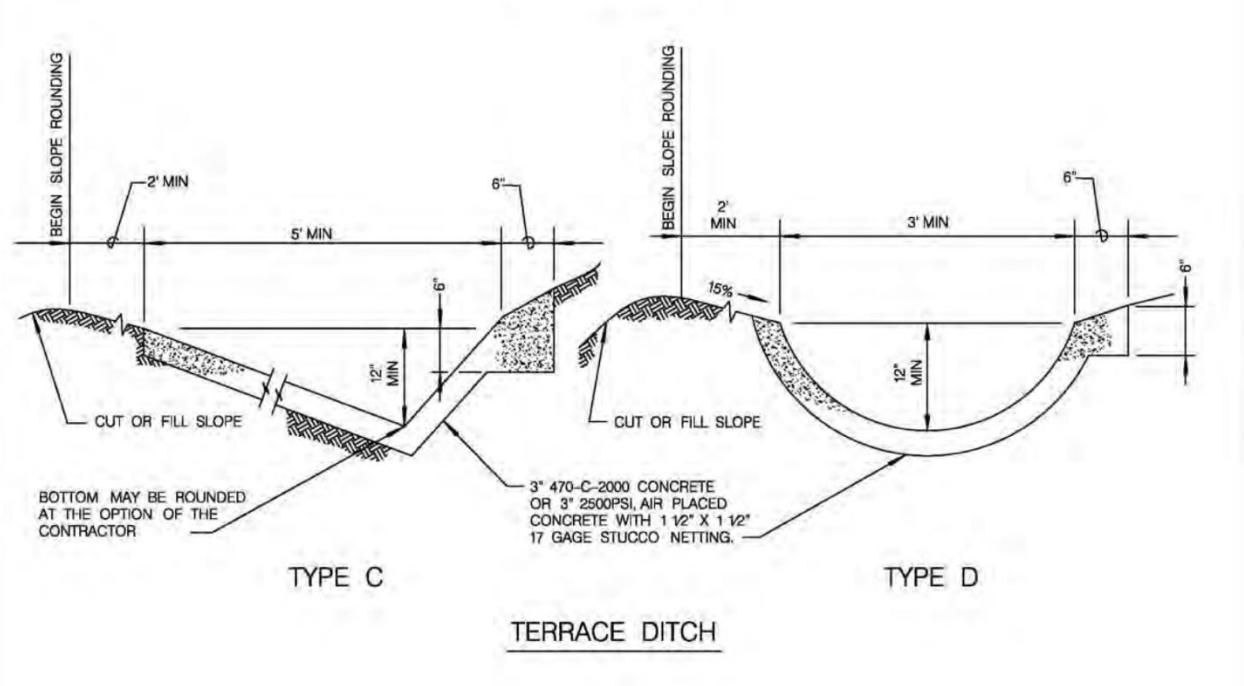


Figure 27. Types of drainage ditches (City of San Diego…, 2016)

Although each design option had its own set of benefits, Hotel Belmar decided concrete with recycled glass aggregate was the best solution, followed by permeable stone pavers. A fine glass aggregate was ultimately chosen because of its sustainability. In 2018 alone, Monteverde recycled an estimated 45.90 tons, or 41650 kilograms, of glass, producing an average of 800.96 kilograms per week (Justin Welch, Environmental Manager of District of Monteverde Aqueduct and Sewer Management Association, personal communication, February 11, 2020). Glass can take up to an estimated one million years to fully decompose, highlighting the importance of reusing and recycling (U.S. Environmental Protection Agency, 2016). The energy saved from recycling just one glass bottle can operate a 100-watt light bulb for four straight hours. As seen in Figure 28, reusing is more environmentally friendly than recycling as it saves the energy that comes with having to dismantle and re-manufacture products (Goadmin, 2015). Since Monteverde is a remote region, the

environmental consequence of transporting thousands of kilograms of glass to the nearest regional recycling center might be greater than the environmental benefit the recycling itself could bring. Hotel Belmar was enthusiastic about repurposing the local output of glass by using it as a fine aggregate in cement. This decision aligns with the hotel's sustainable initiative as well as their interest in accessibility and maintaining the natural aesthetics.

Figure 28. Waste Minimization Hierarchy (Office of Legacy Management, 2017)

Although glass aggregate has a lower absorption rate, a 2% slope towards the road leading to a gutter system would displace any water that would otherwise pool atop the sidewalk. This design is corrugated to prevent slipping, and much more accessible to individuals who are disabled. The use of colored glass aggregate would help to foster continuity between the sidewalk and the surrounding landscape, and not detract from the natural feel of the walkway. After making their decision, Hotel Belmar began preparations to install a recycled glass aggregate concrete sidewalk.

4.4 Determined How Best to Inform the Local People on the Benefits of Sidewalks and Sidewalk Design Options

Landowners neighboring the Hotel Belmar were invited to take part in our town hall. Along with these invitees, other people of interest including Floribeth Rojas, the civil engineer for the municipality, a representative from Hotel Belmar, and a local woman with mobility constraints were in attendance. There was a total of 11 attendees. The town hall began by discussing the importance of sidewalks including the safety of pedestrians and motorists, the continuity and maintenance of safe

walking spaces, and preserving the natural aesthetic of Monteverde. The rules and regulations for sidewalks, both the standing legislation and our proposed specifications, were also discussed to make certain that locals knew what was expected of them.

The different characteristics of this stretch of land were highlighted with respect to the types of materials and designs that would work best in these locations. We showcased the different designs addressing the challenges posed by different constraints including the varying landscape. The attendees provided their opinions on the safety, convenience, cost, and aesthetics of each design. These sidewalk designs can be found in Appendix C.

Along with this discussion, various concerns were brought forth from members of the community. Some commonly raised concerns regarded materials and designs. The attendees questioned what material would be the most environmentally and economically friendly as well as which would be the most accessible for people with disabilities. This concern was addressed by one of the attendees, who has spent years confined to a wheelchair. She said that in her experience, the most accessible sidewalk material was concrete, as it allows for more effortless wheelchair travel.

The attendees recognized that concrete would be the most accessible material, but also acknowledged the negative environmental effects that concrete can have. One of the impacts discussed was the creation of runoff. With more areas in Monteverde being paved, there is less surface area that allows for permeation of rainwater. In turn, the runoff produced often travels far distances before exiting the roadways naturally into adjacent ponds and streams. Some materials displayed by our team had higher permeability than others. Concrete, for example, has low permeability, but our gravel design allows for much more water percolation. Gravel, however, does not provide the surface needed for wheelchair access.

Following this, a discussion ensued regarding how the environmental impact of concrete could be reduced with alternative aggregates. Glass was favored since it would not decompose like the coconut shells or leach microplastics as it degrades like the rubber aggregates would. A question then arose about the combustion properties of the glass aggregate. The attendees were concerned that as the glass heats up in the sun, it could potentially combust, affecting surrounding areas. They were assured that if the glass was used as a fine aggregate, the likelihood of combustion was low. The risk comes with the use of glass as a coarse aggregate as the larger pieces could refract more light than the smaller pieces and start a fire. Another issue brought up regarded whether or not the glass would become slippery in the rain. This again was addressed by pointing out that the slipping hazard was much lower with the fine glass aggregate than the coarse aggregate, as the fine aggregate has a smaller surface area to slip on. As glass is produced in large volumes in Monteverde, it would be

readily available and easy to repurpose (Justin Welch, Environmental Manager of District of Monteverde Aqueduct and Sewer Management Association, personal communication, February 11, 2020).

The attendees also considered the possible collaboration between businesses, residents, and the municipality. They discussed how collaboration between landowners would not only ease the financial burden of the project, but also encourage communication between different members of the community, subsequently strengthening it. As was brought up in our meeting with the municipality council, there were concerns regarding the responsibility of sidewalk installation. When sidewalks can only be installed on one side of the road, participants questioned whom the responsibility would fall upon and whether the task would be equally distributed between property owners on both sides of the road. The participants of the town hall spoke about the importance of coordinating efforts with neighbors so they could work together to devise a plan that would ensure the equal participation of all parties involved.

Guests discussed the possibility of paving the road between Hotel Belmar and the gas station and how this would subsequently affect the timeline of the sidewalk installation. Installing sidewalks prior to paving the road could cause issues as the boundaries of the roadway are not currently defined. This makes it impossible to construct a sidewalk that would not interfere with these boundaries when they are established.

This town hall not only provided an opportunity for residents to voice their opinions and concerns about sidewalks, but also gave us invaluable insight into matters we had not previously considered, such as the ignition properties of the glass aggregate. The town hall also provided a first instance for community members to address their issues in a collaborative way and hopefully will be a method to continue these conversations in the future. This information was later used to improve the manual we created which CORCLIMA will later distribute to the locals.

4.5 Created a Manual of Design Options That Locals Can Utilize When Implementing Their Own Sidewalks

As the current municipal regulations stand, landowners are responsible for building and maintaining sidewalks; however, landowners may be hesitant to surrender a piece of their property to install a sidewalk (Floribeth Rojas & Katy VanDusen, personal communication, January 28, 2020). In order to address this social concern, we incorporated the advice obtained from locals through our

interviews and the town hall to ensure the implementation of sidewalks was viewed as a collaborative community improvement project.

We created an informational manual, found in Appendix D, containing information about current regulations and the benefits of having sidewalks, as well as step by step installation instructions for each of the sidewalk designs we had developed. Installing sidewalks could benefit pedestrians by preventing them from having to walk along muddy paths that could slow them down, trip them, or make their walk unpleasant. Sidewalks would also increase accessibility by providing a smooth surface to walk on, unobstructed by tree roots or large rocks. Obstructed walkways could force a pedestrian to leave the designated path and instead walk on the road, which poses a risk for both pedestrians and drivers. A sidewalk network could benefit the community by decreasing pedestrian related motor vehicle accidents and increasing safety when walking to destinations (U.S. Department of Transportation, 2019). The manual also includes reasons why sidewalks are important to the Monteverde community in particular and how installing sidewalks can contribute to the town's overall safety, character, and tourist appeal.

Providing infrastructure such as sidewalks may prove to be a challenging task for some, as they may encounter monetary constraints, lack of access to materials, or simply a lack of knowledge on how to develop a safe, sustainable sidewalk. Through our interviews with local persons, as well as the town hall we hosted, we gained more knowledge regarding what the residents of Monteverde wanted and needed in order to comply with the local law. One of the suggestions the locals made encouraged collaboration between local businesses and neighbors. Collaboration would not only allow for ease of installation and continuity of design, but also provide economic support for those who need it. Other issues of importance the locals brought to our attention were the accessibility, aesthetics, material sourcing, and runoff mitigation of the sidewalk. Addressing the concerns of locals in our manual allowed us to design sidewalks that fit the many constraints landowners may face, making it more feasible for them to comply with the current law.

The manual created gives local landowners a resource to help them install economically feasible, safe, and environmentally friendly sidewalks. An unformatted version of this manual was submitted to CORCLIMA for further modification. Once they have finalized the manual, CORCLIMA will translate it to Spanish and distribute it through their website.

Through this project, we aimed to provide the residents of Monteverde with the initial tools necessary to expand the coordination efforts for sidewalk infrastructure across the government, the private sector, and non-governmental organizations. By completing this project, we hoped to help

increase road safety, decrease the occurrence of pedestrian traffic-related injuries, and improve the pedestrian experience. In the next chapter, we will discuss further recommendations.

5. CONCLUSIONS AND RECOMMENDATIONS

Based on our research and the results, we were able to reach a number of conclusions regarding sidewalks in Monteverde, Costa Rica. We used these conclusions to make recommendations to both the Monteverde Municipality and our sponsor, CORCLIMA, so that they can continue our work and bring more safe, reliable sidewalks to Monteverde. We have also made recommendations for further research into traffic accidents in the area in order to determine where in Monteverde sidewalks are most needed.

5.1 Conclusions

5.1.1 There is a Lack of Adequate Sidewalk Infrastructure in Monteverde

Monteverde is missing adequate sidewalk infrastructure. The only safe, reliable sidewalks seem to be located closer to Santa Elena, leaving other areas in Monteverde without a safe place for pedestrians to walk. When sidewalks are present in these areas, they are often in disarray or inaccessible, turning these sidewalks into a safety hazard. From semi-structured interviews with local residents we were able to conclude that many locals are unaware that the responsibility of building and maintaining sidewalks falls on them, not the municipality. There are landowners that are aware of their responsibilities but are unable to afford sidewalk installation or simply do not know how. All of these factors have contributed to the current lack of sidewalks and have to be addressed in order to move forward in creating comprehensive sidewalk infrastructure throughout Monteverde.

5.1.2 Community Based Promotion Strategy of Deliverables

When our team first began considering how we would share our designs and the other information we obtained from the local community, we realized it could be difficult to convince them to install sidewalks. There are many obstacles to account for and overcome, such as a lack of technical knowledge, funding, or prior experience installing sidewalks. Through our interviews with locals, we learned that we needed to market our ideas as a community based participatory installation plan in order to gain the support and participation of the local population. It was clear through our project that residents value collaboration with neighbors and others in the community.

5.2 Recommendations

5.2.1 Further Adaptation and Distribution of the Manual

The sidewalk manual that was developed over the course of our time in Monteverde is a good start but requires further adaptation as more local ideas and opinions are investigated and expressed. We recommend that our sponsor, CORCLIMA, continues to speak to locals and gather their thoughts and perspectives on the manual and make changes to it accordingly. This way, the manual can constantly stay up to date in order to better serve the Monteverde community. We also recommend that CORCLIMA distribute paper copies of the manual at the Monteverde Community Fund office, the Monteverde Institute, and the Monteverde Municipality. The Monteverde Community Fund is dedicated to supporting projects that better the community and their office is located in a heavily populated market square making it a perfect place to distribute the manual. The Monteverde Institute is a central hub of activity in the community where locals frequently meet and collaborate. Many Monteverde residents visit the municipality often to address concerns they have with regards to their property, including sidewalk infrastructure. It is our belief that placing copies in these key locations would allow us to reach the people that would benefit most from this manual. In addition to this, we recommend that a copy of the manual should be posted on the CORCLIMA website for individuals who know how and prefer to use the internet. Finally, when the manual has been completed and is ready to distribute, a message should be sent by CORCLIMA to the many WhatsApp group chats that are used to circulate information throughout the community.

5.2.2 Recommendations for Semi-Annual Town Hall Meetings

As proved in the inaugural town hall held as a part of this project, a town hall meeting can be the perfect place for residents to congregate and share their thoughts about sidewalks in Monteverde. It would also be a perfect location for them to improve the manual and recommend what changes should be made. For this reason, we recommend that CORCLIMA and the municipality hold town hall meetings twice a year to discuss the progress of sidewalks and safety in Monteverde. It is recommended that these meetings be held directly before and after the rainy season, as weather is one of the biggest factors that must be considered when building any infrastructure in Monteverde. These meetings should provide locals with a voice to express any concerns they may have with regards to sidewalk installations in Monteverde or the manual. We recommend that CORCLIMA address these concerns as they arise and make changes to the manual accordingly to keep it up to date with solutions to the issues affecting the residents of Monteverde. We also recommend that CORCLIMA

holds these meetings in conjunction with the municipality. By doing so, the municipality will also be kept up to date with the community's issues and be able to address the concerns quickly. Local businesses should also be in attendance, since their help with constructing sidewalks will be solicited in this process. It is our hope that these meetings can also serve to strengthen the coordination efforts CORCLIMA, the Monteverde Municipality, and the Monteverde residents.

5.2.3 Recommendations for Future Research

As of now, there is very little research into the traffic accidents involving pedestrians in Monteverde. Having this information could aid Monteverde greatly with sidewalk development. We recommend that CORCLIMA and the Monteverde Municipality begin gathering information on pedestrian traffic accidents such as where they happen, their severity, and how many fatalities occurred. They could also use information regarding the number of walkers and the number of drivers in an area to see which places sidewalks are most needed or are used and need to be maintained. In addition to this, studies into population growth estimates for the next 20-50 years and how this will affect traffic in the Monteverde region could be very helpful to assessing the need for a comprehensive sidewalk plan in the upcoming decades. With this data, the municipality and CORCLIMA will know where to concentrate their efforts in order to keep the pedestrians safe.

In conclusion, the results of our analyses showed the need for an improvement to the infrastructure and a community-based approach to sidewalk installation. Developing the cognizance of why sidewalks would benefit the community as well as how to properly implement them can be accomplished by the distribution of a sidewalk installation manual, holding biannual town hall meetings, coordination between landowners and businesses, and conducting further research into pedestrian accidents. Through these actions, the Monteverde community will become a safer place for pedestrians and motorists alike.

REFERENCES

ADA Solutions. (2019). Government regulations on tactile warning surfaces. Retrieved from https://adatile.com/govt-regs/

Alvarado, L. (2017, December 27). Costa Rica Continues to Average Over 1 Death Daily as a Result of Road Crashes. *The Costa Rica Star*. Retrieved from https://news.co.cr/costa-rica-continues-average-1-death-daily-result-road-crashes/69444/

Amador, E.A. (2004). *Globalization, ecotourism, and development in the Monte Verde Zone, Costa Rica* (Master's thesis). Retrieved from http://scholarcommons.usf.edu/cgi/viewcontent.cgi?article=1939&context=etd

Agarwal, P. & Oursler, A. (2017, November 14). BBB RED (Research Exchange Develop): Sidewalks. Retrieved from https://www.beyerblinderbelle.com/stories/164_bbb_red_research_exchange_develop_sidewalks

Azetsop, J. (2010). Social justice approach to road safety in Kenya: Addressing the uneven distribution of road traffic injuries and deaths across population groups. *Public Health Ethics, 3*(2), 115-127. doi:10.1093/phe/phq013

Bani-Hani, K. A., & Senouci, A. (2015). Using Waste Tire Crumb Rubber As an Alternative Aggregate for Concrete Pedestrian Blocks. Jordan Journal of Civil Engineering, 9(3), 400–409. doi: 10.14525/jjce.9.3.3080

Beckett, K. (2019, March 30). In Lisbon, a Carpet of Stone Beneath Their Feet. Retrieved from https://www.nytimes.com/2019/03/30/fashion/pavements-limestone-lisbon-portugal.html

Berg, N. (2014, May 22). The sidewalk of the future is not so concrete. *Citylab*. Retrieved from https://www.citylab.com/life/2014/05/the-sidewalk-of-the-future-is-not-so-concrete/371377/

Borough of West Chester. (1973, June 13). Borough of West Chester, PA: Reports of Defective Sidewalks and Curbs. Retrieved from https://ecode360.com/6470358

Chandratilake, R. & Kuruppu, G. (2012, June 28). Use of Recycle Glass as a Coarse Aggregate in Concrete. Retrieved from https://www.irbnet.de/daten/iconda/CIB_DC25129.pdf

City of London. (2016, July 1). City Public Realm Technical Manual. Retrieved from https://www.cityoflondon.gov.uk/services/environment-and-planning/city-public-realm/Documents/city-public-realm-technical-manual.pdf

City of San Diego Standard Drawings for Public Works Construction. (2016). Standard Drawings, 52.

City of Syracuse. (2009). Sidewalk Snow Removal. Retrieved from http://www.syracuse.ny.us/sidewalks-in-winter.html

Climate-Data. (2018). Los Llanos de Monteverde Climate. Retrieved November 10, 2019, from https://en.climate-data.org/north-america/costa-rica/puntarenas/los-llanos-de-monteverde-637892/

Cobb, M. (2017, May 23). To pave or not to pave? Monteverde's ongoing roadway saga. *The Tico Times*. Retrieved from https://ticotimes.net/2017/05/23/pave-not-pave-monteverdes-ongoing-roadway-saga

Construction. (n.d.). Retrieved from https://action-materials.com/category/construction

Das, H., & Goswami, S. (2018, December 4). Where are the footpaths? A case for protecting pedestrian rights in India: . Retrieved from https://thecityfix.com/blog/where-are-footpaths-case-protecting-pedestrian-rights-india-himadri-das-sahana-goswami/

Degreas, H. N., Katakura, P., & Santos, C. R. (2014, July 3). By São Paulo sidewalks: urban form and walkability. Retrieved from https://www.researchgate.net/publication/265157326_By_Sao_Paulo_sidewalks_urban_form_and_walkability

Doustmohammadi, M., Bidabadi, N. S., Kesaveraddy, S., & Anderson, M. (2018). The Impact of Sidewalks on Vehicle-Pedestrian Crash Severity. International Journal of Statistics and Probability, 7(4), 69. doi: 10.5539/ijsp.v7n4p69

Enming Stone. (n.d.). Recycled Glass Concrete Terrazzo for Countertops. Retrieved from https://www.chinaartificialstone.com/recycled-glass-concrete-terrazzo-for-countertops_p35.html

Evans-Cowley, J. (2006). Sidewalk planning and policies in small cities. *Journal of Urban Planning and Development, 132*(2), 71-75. doi:10.1061/(ASCE)0733-9488(2006)132:2(71)

Goadmin. (2015, August 15). THE THREE RS & THE DIFFERENCE BETWEEN RECYCLING & REUSING. Retrieved from https://www.clearancesolutionsltd.co.uk/our-reuse-and-recycling-success-as-green-as-it-gets/the-three-rs-the-difference-between-recycling-reusing/

Government of Clark County, Washington. (2019, December 25). Standard Details. Retrieved from https://www.clark.wa.gov/public-works/standard-details

Gunasekaran, K., Annadurai, R., & Kumar, P. (2012). Long term study on compressive and bond strength of coconut shell aggregate concrete. Construction and Building Materials, 28(1), 208–215. doi: 10.1016/j.conbuildmat.2011.08.072

He, P., Lu, J. X., Poon, C. S., & Yan X. (2019, October 10). Sustainable design of pervious concrete

using waste glass and recycled concrete aggregate. Journal of Cleaner Production, 234, 1102-1112. doi:https://doi.org/10.1016/j.jclepro.2019.06.260

Henfling, I. (2014). Sidewalks in Costa Rica are different. Retrieved from https://www.godutchrealty.com/costa-rica-real-estate-blog/costa-rica-living/sidewalks-costa-rica-are-different/

Hyde, R. & Watts, C. (2013). Challenging Sites. Retrieved from www.yourhome.gov.au/you-begin/challenging-sites

Indiana Department of Environmental Management. (2007). Planning Principles & Design Considerations. In *Indiana Storm Water Quality Manual* (pp. 66-124). Indianapolis, IN: Indiana Department of Environmental Management.

Instituto Nacional de Vivienda y Urbanismo. (2012, December 6). Disposiciones Generales para Edificios. Retrieved from http://www.pgrweb.go.cr/scij/Busqueda/Normativa/Normas/nrm_articulo.aspx?param1=NRA&nValor1=1&nValor2=53161&nValor3=91036&nValor5=5

Kayo, C., Watanabe, C., Sasaki, T., Kumagai, S., Noda, R., & Hashimoto, S. (2015). Life cycle greenhouse gas emissions of woodchip-paved walkways using tsunami salt-damaged wood: Examination in otsuchi, iwate prefecture. *Journal of Wood Science, 61*(6), 620-629.

McMahon, P. J., Zegeer, C. V., Duncan, C. L., Knoblauch, R. R., Stewart, J. J., & Khattak, A. undefined. (2002). An Analysis Of Factors Contributing To "Walking Along Roadway" Crashes: Research Study And Guidelines For Sidewalks And Walkways. Retrieved from http://www.pedbikeinfo.org/cms/downloads/WalkingAlongRoadways_Study_Guidelines.pdf

Mehta, K. P. (2001, October 1). Reducing the Environmental Impact of Concrete. Retrieved from https://www.concrete.org/publications/internationalconcreteabstractsportal/m/details/id/10735.

Mendoza, J. F., Oliver-Solà, J., Gabarrell, X., Rieradevall, J., & Josa, A. (2012). Planning strategies for promoting environmentally suitable pedestrian pavements in cities. *Transportation Research, Part D, 17*(6), 442-450. doi:10.1016/j.trd.2012.05.008

Monteverde Cloud Forest Biological Preserve. (2019). Cloud Forest Climate. Retrieved from https://cloudforestmonteverde.com/

Monteverde Travel Guide. (2018). Monteverde, Costa Rica. Retrieved from https://www.monteverdeinfo.com/

Moss, A. M. (1999). Tree farm raises tropical hardwoods. *FDM.* Retrieved from

https://search-proquest-com.ezproxy.wpi.edu/docview/200121062?accountid=29120&rfr_id=info%3Axri%2Fsid%3Aprimo

Municipality of Heredia. (2018, February 12). Reglamentos. Retrieved from https://www.heredia.go.cr/sites/default/files/reglamento_para_el_cobro_de_tarifas_y_multas_por_omisiones_a_los_deberes.pdf

Municipality of Puriscal. (2011, May 31). Reglamento de Aceras. Retrieved from http://www.municipalcr.com/index.php?option=com_content&id=5551:reglamentos-municipalidad-puriscal&Itemid=50

Municipality of San José. (n.d.). Artículo 10. Retrieved from http://www.pgrweb.go.cr/DOCS/NORMAS/1/VIGENTE/RM/2010-2019/2010-2014/2014/12B64/F6F11.HTML

Naik, T. R. (2008). Sustainability of concrete construction. *Practice Periodical on Structural Design and Construction, 13*(2), 98-103. https://doi.org/10.1061/(ASCE)1084-0680(2008)13:2(98)

Nassar, R.-U.-D., & Soroushian, P. (2012). Strength and durability of recycled aggregate concrete containing milled glass as partial replacement for cement. Construction and Building Materials, 29, 368–377. doi: 10.1016/j.conbuildmat.2011.10.061

Office of Legacy Management. (2017, October 17). Waste Minimization and Pollution Prevention. Retrieved from https://www.energy.gov/lm/articles/waste-minimization-and-pollution-prevention

Outdoor Timber Performance. (2014). Timber Queensland. Retrieved from http://www.hyne.com.au/documents/Feature Documents/TQ_25_Outdoor-Timber-Performance_final.pdf

PAVEGEN. (2019). Smart Cities - Connecting people to places. Retrieved from https://pavegen.com/smart-cities/

Peckenham, E. (2016). 11 green building materials that are way better than concrete. Retrieved from https://inhabitat.com/11-green-building-materials-that-are-way-better-than-concrete/

PermaTrak. (2019). Boardwalk maintenance costs: wood vs. composite vs. concrete. Retrieved from https://www.permatrak.com/features-benefits/boardwalk-maintenance-costs

Pierce, C. C. (1930). Old wooden sidewalks in Mariposa, CA.1930. Mariposa, CA: California Historical Society. Retrieved from http://digitallibrary.usc.edu/cdm/ref/collection/p15799coll65/id/18997

Recycled Glass Concrete Terrazzo Tiles. (n.d.). Retrieved from https://www.chinaartificialstone.com/recycled-glass-concrete-terrazzo-tiles_p125.html

Roberson, A. (2007, September 7). San José Municipality Overhauling Sidewalks. Retrieved from https://ticotimes.net/2007/09/07/san-jose-municipality-overhauling-sidewalks

Rojas, Z. (1988). *Código Municipal Comentarios, Jurisprudencia*. San José, CR: Instituto de Fomento y Asesoría Municipal. https://www.munisc.go.cr/Documentos/NuestraMunicipalidad/C%C3%B3digo%20Municipal.pdf

Shafigh, P., Mahmud, H. B., Jumaat, M. Z., & Zargar, M. (2014). Agricultural wastes as aggregate in concrete mixtures – A review. Construction and Building Materials, 53, 110–117. doi: 10.1016/j.conbuildmat.2013.11.074

Sonawane, Y. N., & Chitte, C. J. (2016). Waste Coconut Shell as a Partial Replacement of Coarse Aggregate in Concrete Mix - An Experimental Study. International Journal of Science and Research (IJSR), 5(4), 649–651. doi: 10.21275/v5i4.nov162608

Stanley, K. (2007, February 2). Officials Focus on Shoddy Sidewalks. *The Tico Times Costa Rica.* Retrieved from https://ticotimes.net/2007/02/02/officials-focus-on-shoddy-sidewalks

Stewart, S. (2017, February 4). Portland Landscaping & Permeable Paving - Landscape East & West. Retrieved from https://www.landscapeeast.com/blog/permeable-paving-portland-landscaping-2015-07

Sohail, U. (2016). This is how sidewalks were first invented. Retrieved from https://wonderfulengineering.com/this-is-how-sidewalks-were-first-invented/

TERRECON. (2014). Overview. Retrieved from https://terrecon.com/products/overview/

Thompson, W. (2018, September 19). 5 Reasons Why Concrete is So Widely Used. Retrieved from https://www.thompsonquarries.co.uk/5-reasons-why-concrete-is-so-widely-used

Tribunal Supremo de Elecciones Normativa. (1996, May 29). Ley de Igualidad de Oportunidades para las Personas con Discapcidad. Retrieved from https://www.tse.go.cr/pdf/normativa/leyigualdaddeoportunidades.pdf

Tulu, G. S., Washington, S., King, M. J., & Haque, M. M. (2013). *Why are Pedestrian Crashes so Different in Developing Countries? A Review of Relevant Factors in Relation to their Impact in Ethiopia.* Paper presented at the Australasian Transport Research Forum, Brisbane, Australia. Retrieved from https://pdfs.semanticscholar.org/597b/6b740ae6a03f35ae9904c6937279e49396da.pdf

United States Department of Agriculture. (2016, August 30). Treated Lumber.

U.S. Department of Transportation. (2019, April 1). Safety Benefits of Walkways, Sidewalks, and Paved Shoulders. Retrieved from https://safety.fhwa.dot.gov/ped_bike/tools_solve/walkways_trifold/

U.S. Department of Transportation. (2013, February 1). Guide for Maintaining Pedestrian Facilities for Enhanced Safety Research Report. Retrieved from https://safety.fhwa.dot.gov/ped_bike/tools_solve/fhwasa13037/research_report/chap2.cfm

U.S. Environmental Protection Agency. (2016, March 20). Environmental Factoids | WasteWise. Retrieved from https://archive.epa.gov/epawaste/conserve/smm/wastewise/web/html/factoid.html

Walking the walk: Sidewalks made of recycled rubber and plastic are cutting infrastructure costs while enhancing the long-term viability of the urban forest. (2009). *Arbor Age, 29*(2), 31. Retrieved from https://link.galegroup.com/apps/doc/A199984945/PPGL?sid=lms

Willow Creek. (n.d.). Paver Installation. Retrieved from https://www.willowcreekpavingstones.com/resources/installation-steps

World Health Organization. (2017). *Save Lives: a road safety technical package*. Geneva.

World Health Organization. (2016). *Road Safety: Number of road traffic deaths and distribution by type of road user, 2013*. Retrieved from http://gamapserver.who.int/gho/interactive_charts/road_safety/road_traffic_deaths3/atlas.html

World Health Organization. (2013, May 2). More than 270,000 pedestrians killed on roads each year. Retrieved from https://www.who.int/mediacentre/news/notes/2013/make_walking_safe_20130502/en/

World Wildlife Fund. (2020). Timber. Retrieved from https://www.worldwildlife.org/industries/timber

APPENDICES

APPENDIX A - INTERVIEW QUESTIONS

English Translation:

We are WPI students who are working with CORCLIMA and Hotel Belmar to devise a manual that will help local individuals install safe, affordable, effective sidewalks. Since you are an avid walker, Katy VanDusen suggested we reach out to you to gather your thoughts related to the current state of the sidewalks throughout Monteverde, what you think has been done well in the past, and what can be improved.

1. Is it okay if we record this interview so we may use the information you have provided later in our research?
2. When walking through Monteverde, it is evident that there are many different materials used, methods of installation, and designs that can be followed when building a sidewalk. In your experience, what is the best sidewalk you have walked on or seen so far in Monteverde?
    1. If you haven't encountered a sidewalk that you particularly like, are there any characteristics of certain sidewalks that you do like?
3. If you could change one major aspect of the sidewalks around Monteverde, what would it be?
4. What issues have you encountered relating to subpar sidewalks? (i.e. safety, need to use different modes of transportation, etc.)
5. Convincing locals to install sidewalks may prove to be an issue for our team - are there any words of wisdom you can give that we can use to persuade individuals to install sidewalks?
6. Do you have any specific experiences or interests that you think may be of use to our project or to the future of Monteverde's sidewalks?
7. Are there any other concerns or comments you would like to voice that we have not yet discussed?

Spanish Translation:

Somos estudiantes de WPI trabajando con CORCLIMA y el Hotel Belmar para diseñar un manual que puede ayudar a las personas locales a instalar aceras seguras, asequibles, y efectivas. Como es un ávido caminante, Katy VanDusen sugirió que nos comuniquemos con usted para reunir sus pensamientos relacionados con el estado actual de las aceras en Monteverde, lo que cree que se ha hecho bien en el pasado, y qué se puede mejorar.

1. ¿Está bien si grabamos esta entrevista para que podamos usar la información que nos proporcionó más adelante en nuestra investigación?
2. Al caminar por Monteverde, es evidente que se utilizan muchos materiales diferentes, métodos de instalación, y diseños que se pueden seguir al construir una acera. En su experiencia, ¿cuál es la mejor acera por la que ha caminado o visto hasta ahora en Monteverde?
    1. Si no ha encontrado una acera que le guste especialmente, ¿hay alguna característica de ciertas aceras que le guste?
3. Si pudieras cambiar un aspecto importante de las aceras alrededor de Monteverde, ¿cuál sería?
4. ¿Qué problemas ha encontrado en relación con las aceras inferiores? (es decir, seguridad, necesidad de usar diferentes modos de transporte, etc.)
5. Convencer a los locales para que instalen las aceras puede ser un problema para nuestro equipo. ¿Hay algunas palabras de sabiduría que nos pueda dar para persuadir a las personas para que instalen las aceras?
6. ¿Tiene alguna experiencia o interés específico que cree que puede ser útil para nuestro proyecto o para el futuro de las aceras de Monteverde?
7. ¿Hay otros comentarios que le gustaría expresar que aún no hemos discutido?

APPENDIX B - PROPOSED REGULATIONS

English Translation:

Proposed Regulations on Sidewalks in the Monte Verde District

Mandatory sidewalk specifications are as follows:

1. Slip resistant
2. At least 20 centimeters high between the ground and the height of the sidewalk up to a maximum of 70 centimeters
3. Parallel to the road with a gradual and constant inclination
4. A minimum of 1.2 meters wide
5. Have a 2% slope towards the street for water drainage
6. Maintain continuity with respect to other sections
7. Have ramps for people with disabilities

Sources: (Municipality of Puriscal, 2011; Municipality of San José, n.d.; Municipality of Heredia, 2018; Floribeth Rojas, Monteverde Municipality civil engineer, personal communication, January 28, 2020)

Railings:

Railings are required if:

1. The height between the road and the top of the sidewalk is greater than 70 centimeters
2. The slope of the sidewalk is greater than 20% if it is directly adjacent to the street
3. There is a 15% or more slope on the surrounding property

The specifications for railings are as follows:

1. They must be 90 centimeters high on the sidewalk when it works as a handrail. They must be 110 centimeters high if it works to protect the pedestrian from falling
2. Must have vertical or diagonal bars to avoid injury or must include a fence

Sources: (Municipality of San José, n.d.; Floribeth Rojas, Monteverde Municipality civil engineer, personal communication, January 28, 2020)

The municipality must approve sidewalk design when:

The height between the street and the top of the sidewalk is greater than 70 centimeters

Source: **(**Floribeth Rojas, Monteverde Municipality civil engineer, personal communication, January 28, 2020)

Drainage

Adequate drainage is needed:

1. When there is sewage and asphalt, the water entrances that allow water to leave the street to the sewer must be located no more than every 15 meters. The drawers must be at least 10 centimeters high and 20 centimeters wide. They must have drainage grates to check the sewer no more than every 50 meters.
2. If no road is paved and there is no sewerage, the cuts must leave where there are natural water flows to farms.
3. The diameter of the sewer system depends on the volume of water that is emptied on that ditch that depends on the topography, the amount of water that enters, and the length that is intended to be tubed.
4. If it is on a sewer, the drain below the sidewalk must be at least 18 inches in diameter and be accessible for regular cleaning. The sewer must be surrounded by stone to keep it in place.
5. Grating for sidewalks must be placed in the opposite direction of travel to prevent tripping and getting stuck in the grate. The holes in the grates should be 3 centimeters in length by 1 centimeter in width. The grate should be 1.2 meters in length by 0.5 meters in width and the height should match the height of the sidewalk. These grates should be cleaned while the rest of the sidewalk is cleaned.
6. There must be a water drainage system next to the sidewalk on the side of the road to allow water flow or it must be underneath and can be cleaned and maintained on a regular basis.

Source: (Floribeth Rojas and Katy VanDusen, personal communication, February 18, 2020)

Vehicular Access:

For places where a vehicle needs to cross a sidewalk:

1. There must be a ramp at a maximum slope of 10% on both sides of the sidewalk to allow the vehicle to cross.
2. These ramps must have a slope of 2% on either side in order to allow for proper water drainage.

Source: (Floribeth Rojas and Katy VanDusen, personal communication, February 18, 2020)

Expectations of landowners:

1. Landowners who border public roads in urban or suburban areas have two years to install continuous sidewalks from the announcement of this regulation. Urban areas count at any place in a city and suburban counts as any place within 5 minutes from the city.
2. Landowners, neighbors and businesses who benefit from the sidewalk are encouraged to collaborate for construction and maintenance.
3. If landowners do not construct the sidewalk according to specifications within two years, the municipality will install it for them. The landowners will be notified a week before construction by the municipality is to begin. The landowners will be charged the cost of installing the sidewalk. This includes fees for materials and labor. They will have one year to pay back the municipality for these charges. If the landowners feel they may not be able to meet this deadline they may prepare a written statement explaining their reasoning in which the municipality will have ten business days to evaluate the request and approve or deny the claim, including the possibility of a monthly payment plan.

Sources: (Municipality of Puriscal, 2011; Floribeth Rojas, Monteverde Municipality civil engineer, personal communication, January 28, 2020)

Municipality	Puriscal	San José	Heredia
Sidewalk minimum width	1.5m	1.2m	1.5m
Has time limits	Yes	No	Yes
Landowners Responsible	Yes	Yes	Yes

Railings	No	Yes	No
Material	Non-slip Concrete	Non-slip Concrete	Non-slip Concrete
Ramps (for disabled)	Yes	Yes	Yes
Sidewalk height from spout	14 cm	N/A	15 cm
Vehicular Access	Ramps that does not block waterflow	Ramps or removable metal grills	Ramp that does not block waterflow
Charge owners costs to build or repair	Yes	Yes	Yes

Citations:

Floribeth Rojas, Monteverde Municipality civil engineer, personal communication, January 28, 2020

Municipality of Heredia. (2018, February 12). Reglamentos. Retrieved from https://www.heredia.go.cr/sites/default/files/reglamento_para_el_cobro_de_tarifas_y_multas_por_omisiones_a_los_deberes.pdf

Municipality of Puriscal. (2011, May 31). Reglamento de Aceras. Retrieved from http://www.municipalcr.com/index.php?option=com_content&id=5551:reglamentos-municipalidad-puriscal&Itemid=50

Municipality of San José. (n.d.). Artículo 10. Retrieved from http://www.pgrweb.go.cr/DOCS/NORMAS/1/VIGENTE/RM/2010-2019/2010-2014/2014/12B64/F6F11.HTML

Spanish Translation:

Regulación Propuesto sobre aceras en el Distrito de Monte Verde

Las especificaciones obligatorias por aceras son las siguientes:

1. Ser antideslizantes
2. Tener al menos 20 centímetros de altura entre el suelo y la altura de la acera hasta un máximo de 70 centímetros
3. Ser paralela a la carretera con una inclinación gradual y constante
4. Tener un mínimo de 1,2 metros de ancho
5. Tener una pendiente de 2% hacia la calle para el drenaje del agua
6. Mantener la continuidad con respeto a otros tramos
7. Tener rampas para personas con discapacidades.

Fuentes: (Municipality of Puriscal, 2011; Municipality of San José, n.d.; Municipality of Heredia, 2018; Floribeth Rojas, Monteverde Municipality civil engineer, personal communication, January 28, 2020)

Barandas:

Se requieren barandas si:

1. La altura entre la carretera y la parte superior de la acera es mayor de 70 centímetros
2. La pendiente de la acera es mayor al 20% si se colinda directamente a la calle
3. Hay una pendiente de 15% o más en la propiedad aledaña

Las especificaciones para las barandas son las siguientes:

1. Deben estar a 90 centímetros de altura sobre la acera cuando funciona como pasamanos
2. Deben estar 110 centímetros de altura si funciona para proteger el peatón de caerse
   Debe tener barras verticales o diagonales para evitar lesiones o debe incluir una valla

Fuentes: (Municipality of San José, n.d.; Floribeth Rojas, Monteverde Municipality civil engineer, personal communication, January 28, 2020)

El municipio debe aprobar el diseño de la acera cuando:

Si la altura entre la calle y la parte superior de la acera es superior a 70 centímetros

Fuente: **(**Floribeth Rojas, Monteverde Municipality civil engineer, personal communication, January 28, 2020)

Flujo de agua

Se necesita un drenaje:

1. Cuando hay alcantarillado y asfalto, los cortes de agua que permiten el agua salir de la calle al alcantarillado deben estar ubicados no más de cada 15 metros. Los tragantes deben tener por lo menos de 10 centímetros de altura y 20 centímetros de ancho. Deben tener cajas de registro donde revisar el alcantarillado no más de cada 50 metros.
2. Si no camino es asfaltado y no hay alcantarillado, los cortes deben salir donde haya flujos naturales de agua hacia fincas.
3. El diámetro del alcantarillado depende del volumen de agua que se vacíe sobre esa cuneta que depende en la: topografía, la cantidad de agua que entra, y el longitud se pretende entubar.
4. Si se encuentra sobre una alcantarilla, el drenaje debajo de la acera debe ser accesible para la limpieza regular. La alcantarilla debe estar rodeada de piedra para mantenerla en su lugar.
5. La rejilla para las aceras debe colocarse en la dirección opuesta de la dirección de la acera para evitar tropiezos y atascarse en la rejilla. Los agujeros en las rejillas deben tener 3 centímetros de largo por 1 centímetro de ancho. La parrilla debe tener 1.2 metros de largo por 0.5 metros de ancho y la altura debe coincidir con la altura de la acera. Estas rejillas deben limpiarse al mismo tiempo que se limpia el resto de la acera.

Fuente: (Floribeth Rojas and Katy VanDusen, personal communication, February 18, 2020)

Acceso de vehículos

Para lugares donde los vehículos necesitan cruzar una acera:

1. Tiene que tener una rampa con una pendiente máxima de 10% en ambos lados de la acera para permitir que vehículos cruzan.
2. Estas rampas deben tener una pendiente de 2% en cada lado para permitir el drenaje adecuado del agua.

Fuente: (Floribeth Rojas and Katy VanDusen, personal communication, February 18, 2020)

Expectativas de los propietarios:

1. Los propietarios que enfrenten las vías públicas en zonas urbanas y semiurbanas tienen 2 años para construir una acera continua desde el anuncio de este reglamento. Se alienta a los propietarios, vecinos y empresarios a colaborar en la construcción y el mantenimiento de las aceras.
2. En zonas semi-urbanas donde la topografía complica mucho la instalación de la acera, se puede hacer de solo un lado mientras que no cruce la calle con frecuencia. El propietario al lado donde no se instala debe colaborar con la construcción al otro lado.
3. Si los propietarios no construyen la acera de acuerdo con las especificaciones dentro de dos años, la municipalidad la instalará para ellos. Se notificará a los propietarios una semana antes de que comience la construcción por parte del municipio. A los propietarios se les cobrará el costo de construir la acera. Esto incluye tarifas por materiales y mano de obra. Tendrán 1 año para pagar al municipio por estos cargos. Si los propietarios consideran que no pueden cumplir con este plazo, pueden preparar una declaración por escrito que explique su razonamiento en el que el municipio tendrá 10 días hábiles para evaluar la solicitud del propietario y aprobar o rechazar el reclamo, incluyendo la posibilidad de un plan de pago mensual.
4. Es importante que se coordinar una inspección por parte del municipio previa para aprobar el diseño.

Fuentes: (Municipality of Puriscal, 2011; Floribeth Rojas, Monteverde Municipality civil engineer, personal communication, January 28, 2020)

Municipalidad	Puriscal	San José	Heredia
Ancho Mínimo de Aceras	1.5m	1.2m	1.5m
Tiene tiempo límite	Sí	No	Sí
Responsabilidad del propietario	Sí	Sí	Sí

Barandas	No	Sí	No
Material	Concreto antideslizante	Concreto antideslizante	Concreto antideslizante
Rampas (por discapacitado)	Sí	Sí	Sí
Altura de aceras de pitorro	14 cm	N/A	15 cm
Acceso de vehículos	Rampas que no bloquea flujo de agua	Rampas o removible rejas de metal	Rampas que no bloquea flujo de agua
Cobra al propietario el precio por construir o reparar	Sí	Sí	Sí

Citas:

Floribeth Rojas, Monteverde Municipality civil engineer, personal communication,

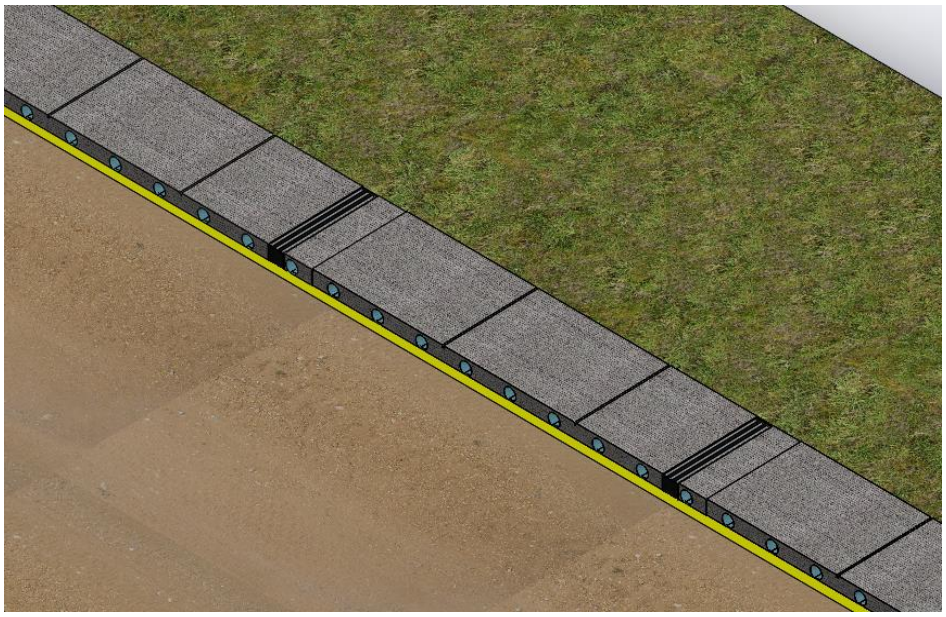
Municipality of Heredia. (2018, February 12). Reglamentos. Retrieved from https://www.heredia.go.cr/sites/default/files/reglamento_para_el_cobro_de_tarifas_y_multas_por_omisiones_a_los_deberes.pdf

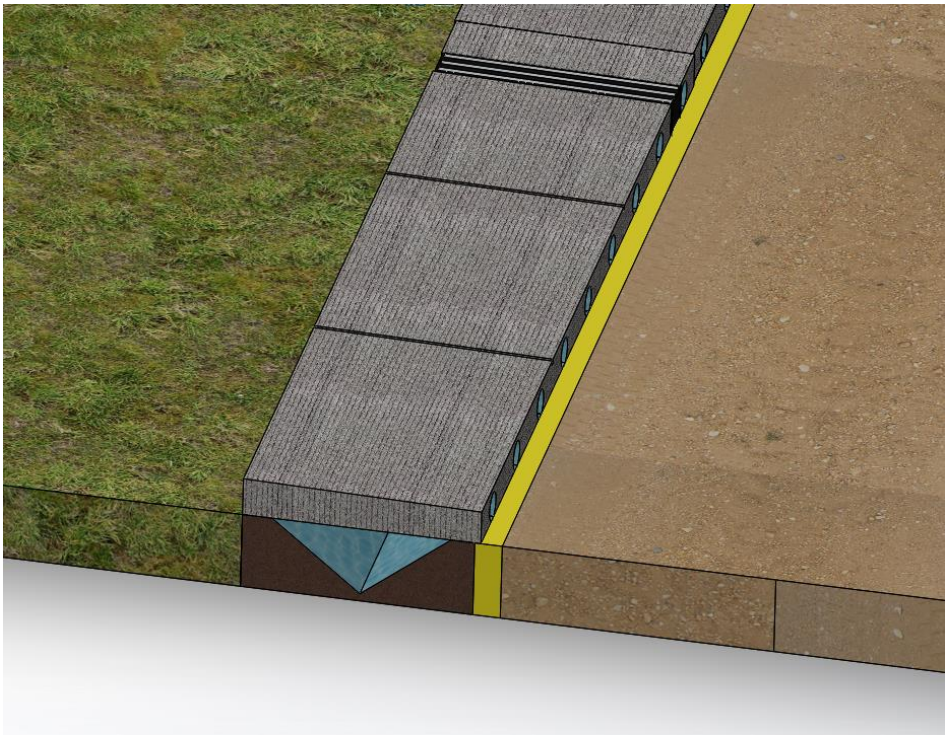
Municipality of Puriscal. (2011, May 31). Reglamento de Aceras. Retrieved from http://www.municipalcr.com/index.php?option=com_content&id=5551:reglamentos-municipalidad-puriscal&Itemid=50

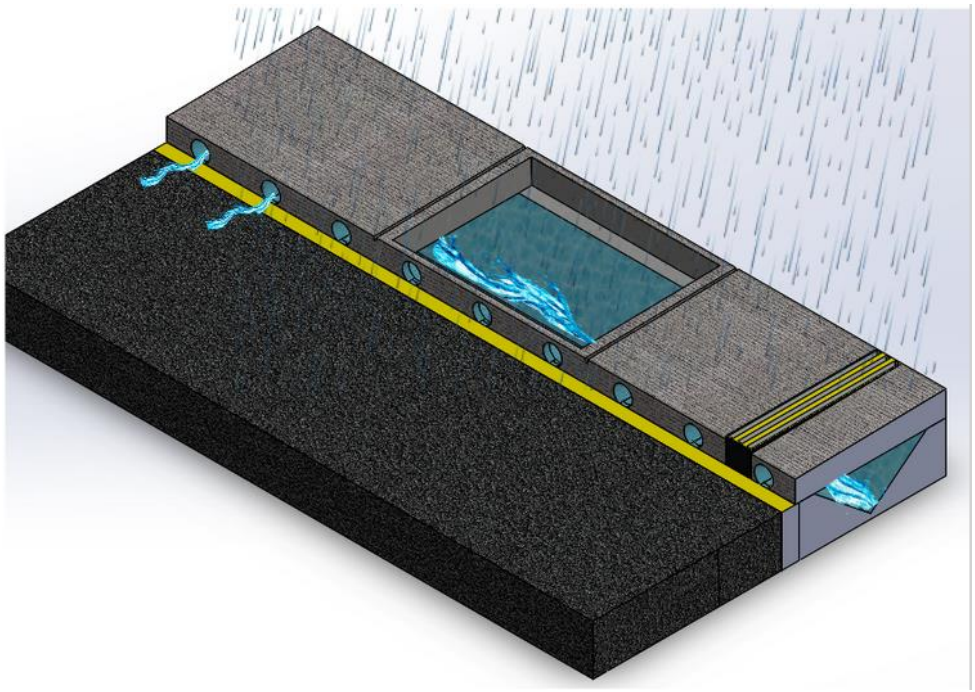
Municipality of San José. (n.d.). Artículo 10. Retrieved from http://www.pgrweb.go.cr/DOCS/NORMAS/1/VIGENTE/RM/2010-2019/2010-2014/2014/12B64/F6F11.HTML

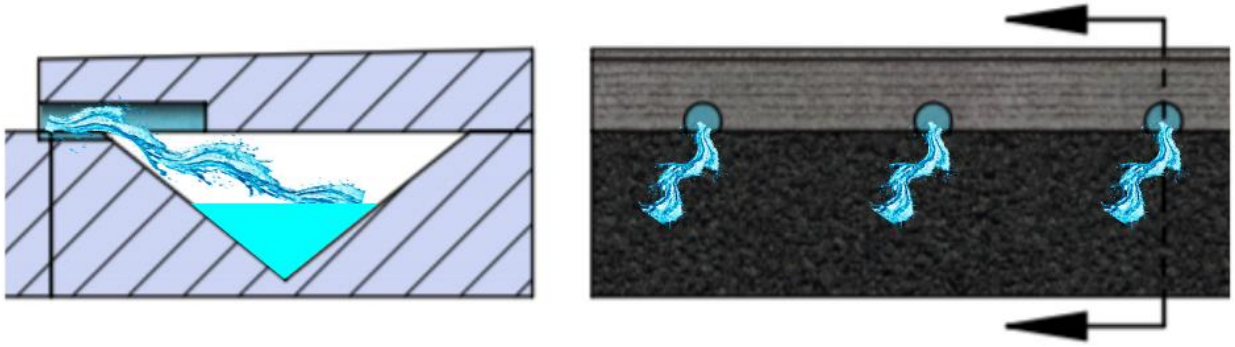
APPENDIX C - SIDEWALK DESIGNS

Design 1:



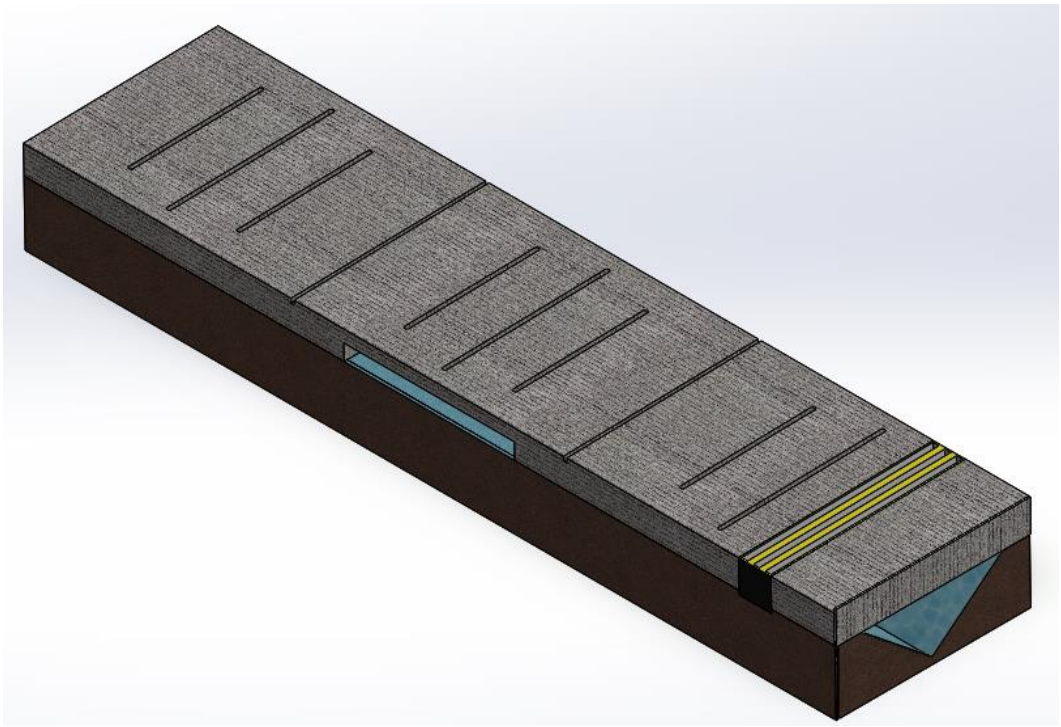


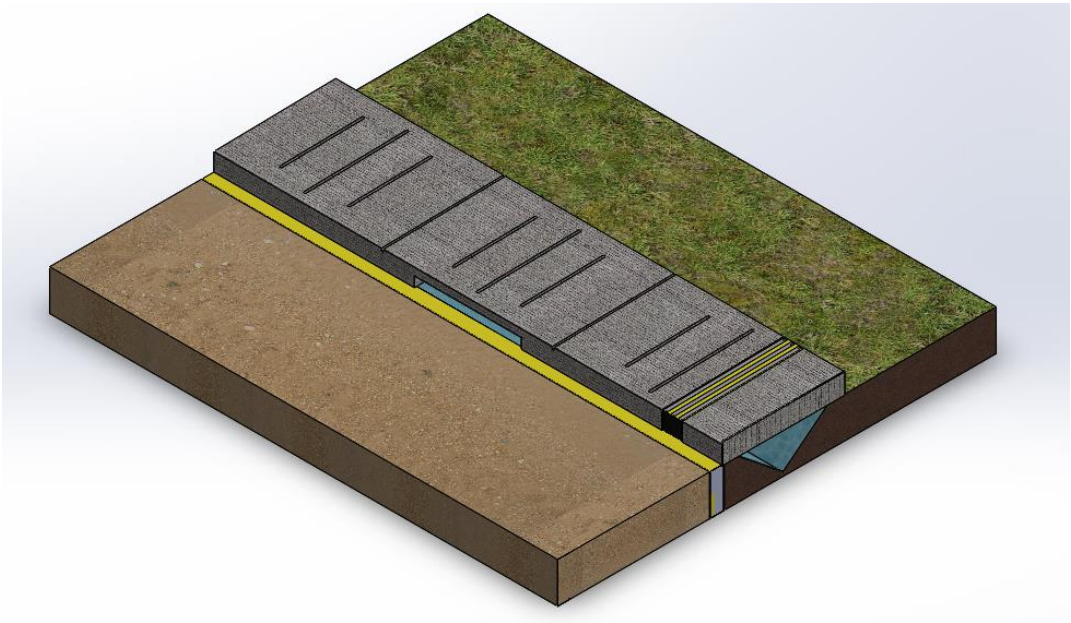




Design 1 is a concrete sidewalk situated over a drainage culvert. There are drainage holes on the side of the sidewalk to allow water from the street to drain into the culvert underneath. This design also incorporates an access grate to clean the culvert of any debris that may have washed into it.

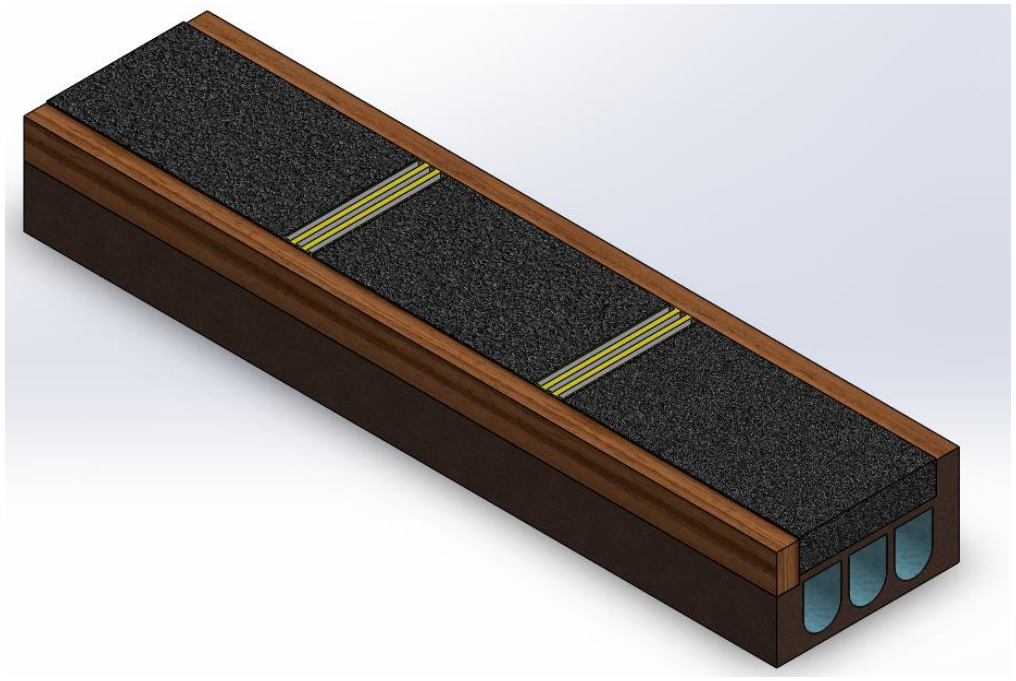
Design 2:

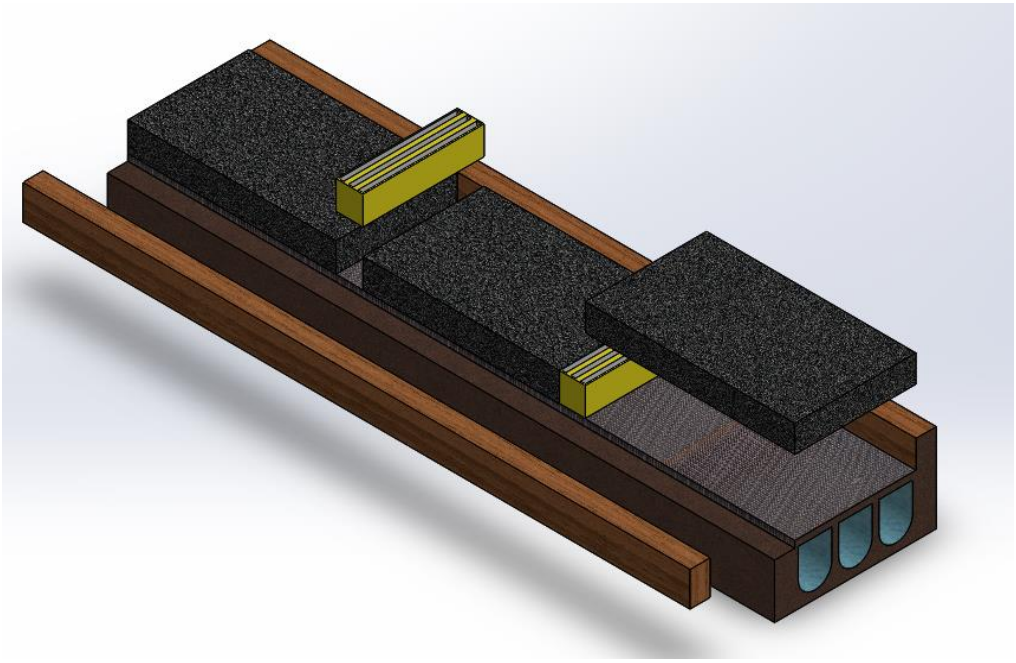




Design 2 is similar to Design 1 except that this design contains slits along the top of the sidewalk for added drainage. There is also a drainage slit on the side of the sidewalk to allow water from the street to drain into the culvert underneath.

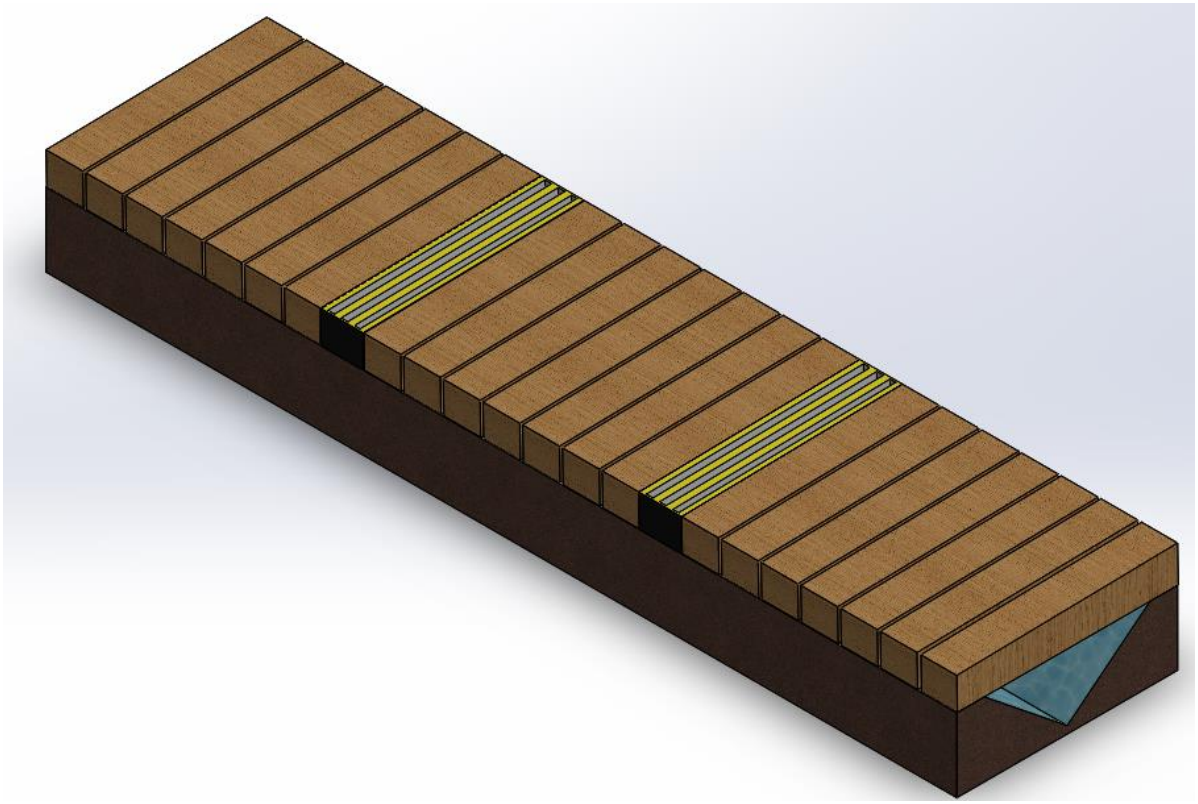
Design 3:





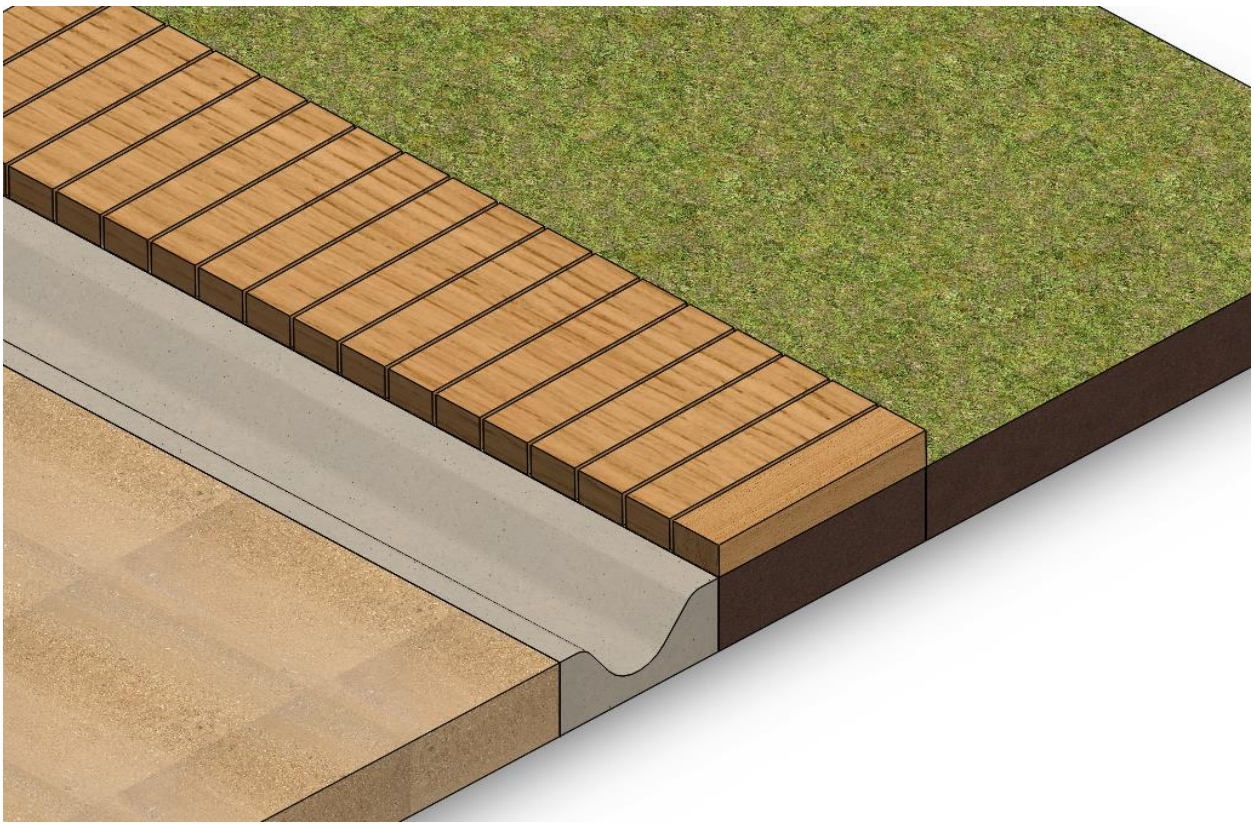
Design 3 is a gravel sidewalk with wood composite siding. Wood composite was chosen for the siding because it is more resistant to rot than normal wood. This design includes a metal mesh underneath the gravel that will prevent gravel from washing into the culvert underneath. There are also access grates to clean the culvert of any debris.

Design 4:



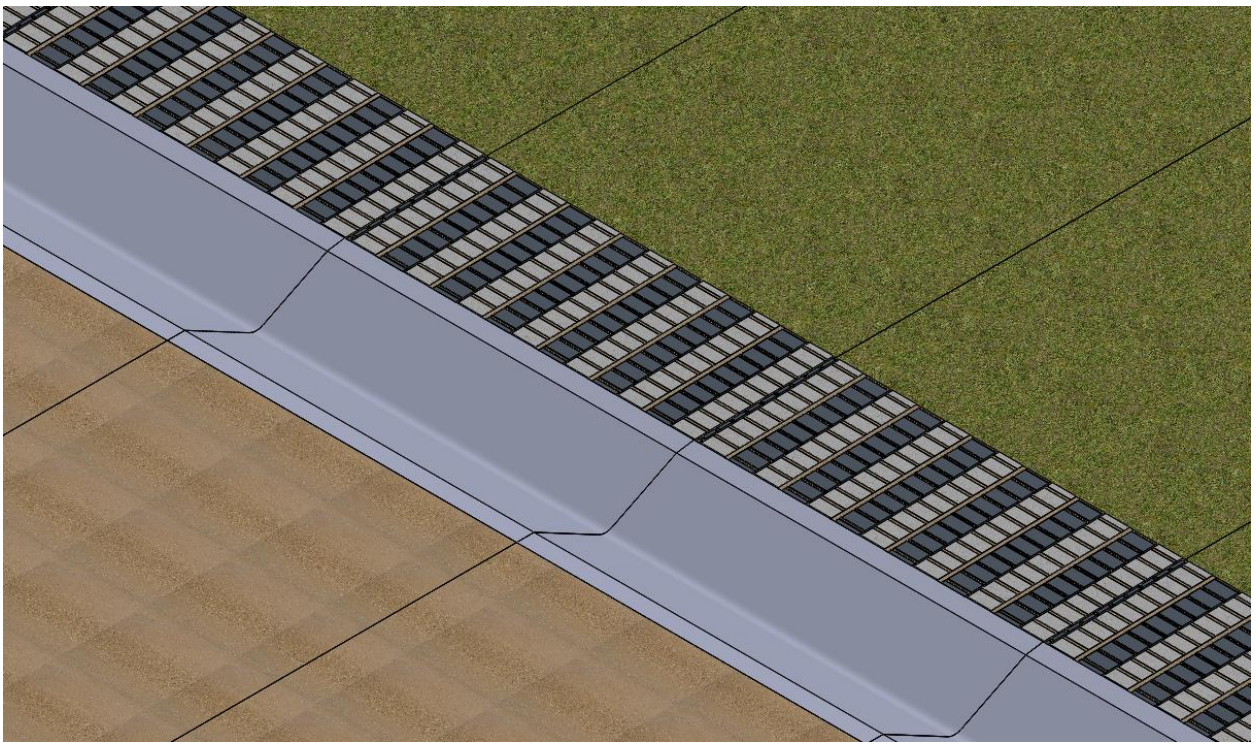
Design 4 is a wood composite boardwalk situated over a culvert. Wood composite was used instead of wood because of its greater resistance to rot. With this design, water permeates through the spacing between each board and into the culvert underneath. Access grates are included to clear the culvert of any debris that may have washed into it.

Design 5:



Design 5 is similar to Design 4. The difference lies in the location of the culvert. Unlike Design 4, this design has the culvert located next to the wood composite boardwalk. The boardwalk has a 2% slope towards the road to allow water to drain into the culvert. This design was created to give the residents of Monteverde a cheaper alternative to Design 4 as placing a culvert underneath a sidewalk is more expensive. The reason for this lies in the additional reinforcement required to place a culvert underneath a sidewalk.

Design 6:



Design 6 is a sidewalk composed of stone pavers. The stone pavers allow water to permeate through the spacing between each stone to be absorbed by the ground underneath. This design is also constructed with a 2% slope towards the road and a culvert located adjacent to the sidewalk to provide additional drainage. Different types of stones can be used and laid out in different patterns, allowing landowners to customize the design and add their own artistic flair to it.

APPENDIX D – MANUAL

SUSTAINABLE SIDEWALKS FOR THE MONTEVERDE COMMUNITY

A Comprehensive Installation Manual for Local Landowners

Made possible by the collaboration of CORCLIMA, Hotel Belmar, and Worcester Polytechnic Institute

HOTEL BELMAR
THE ART OF NATURE

corclima
ENFRENTANDO EL CAMBIO CLIMÁTICO

WPI

Overview

Sidewalks play a critical role in the safety of pedestrians by keeping them off the street and away from traffic. In general, sidewalks are pathways adjacent to roadways that are designated for pedestrian travel. Without them, individuals become at risk along any roadway. In Monteverde, Costa Rica, there is a lack of sidewalk infrastructure for many reasons including local legislation, environmental concerns, and installation constraints. The collaborators of this project aimed to introduce a participatory process for the installation of safe, accessible, continuous sidewalks throughout the Monteverde Municipality. They aimed to meet this goal through community collaboration.

In order to do so they determined local opinion related to the existing state of sidewalks in Monteverde and identified regulations or improvements to regulations pertaining to sidewalks for the Monteverde Municipality. They also determined the material and installation constraints that would be experienced in Monteverde, as well as how to inform the local population on the benefits of sidewalks and sidewalk design options. With this information, they were able to develop a plan for a participatory project for widespread sidewalk installation in Monteverde.

About the Collaborators

The Hotel Belmar is a private organization opened in 1985 and run by the Belmar family. It is a small business with 11-50 employees and a mission to provide a unique experience to their guests while also having a commitment to the preservation of the environment and the local community (Hotel Belmar, 2016a). The Certificate for Sustainable Tourism, sponsored by the Costa Rica Tourism Board, is a program recognized globally, in which tourism companies are rated on a scale of 1-5 for how sustainable their business is. Hotel Belmar was rated a five in 2011, and is the only hotel in Monteverde, Costa Rica, with a level five rating (Hotel Belmar, 2016c). To help sponsor the construction of the sustainable, environmentally friendly sidewalks, Hotel Belmar is partnering with the Commission for Resilience to Climate Change in Monteverde (CORCLIMA). CORCLIMA is a non-profit organization with a mission to tackle climate change and to take care of the environment at a community level (CORCLIMA, 2019).

Funded by the Guanacaste Community Fund (GCF) and more specifically the CRUSA fund, CORCLIMA's main goal is to reduce the effects of climate change in Monteverde. The GCF offers a variety of different grants supplied by donors across the world that can be used to support projects all around Costa Rica (Fondo Para…, n.d.). The CRUSA fund is a matching grant program that has funded CORCLIMA projects in the past, and can be applied for again in the future. There are also people involved with CORCLIMA that have a vast impact on the community, such as the mayors of the Monteverde District and members of the Monteverde District Council. Some of the other collaborators of CORCLIMA include Asomove, Biblioteca Pública Interactiva, and Acepesa (CORCLIMA, 2019). In the past, the GCF has supplied CORCLIMA with a grant to inventory greenhouse gas emissions in the Monteverde region, and devise a plan for their reduction (CORCLIMA, 2019).

Students from Worcester Polytechnic Institute (WPI) are working with these two organizations to bring this project to fruition. The students developed this manual and other designs, created deliverables, completed interviews, and identified objectives in order to attain the stated goal.

Table of Contents

The Importance of Sidewalks

SECTION 1

Sidewalks: Facts & Figures

Why Install Sidewalks?

1. In 2007, 5-year-old Mayeli Guiselle Flores was struck and killed by a truck in the suburbs of Santa Ana, Costa Rica (Stanley, 2007). She was walking on a street that lacked a sidewalk.

2. In 2013 alone, there were 216 pedestrian deaths and 61 cyclist deaths as a result of traffic accidents in Costa Rica (WHO, 2016).

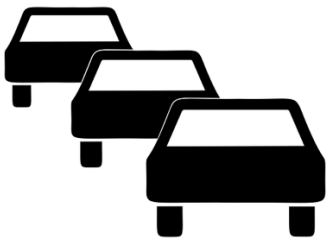
3. In Monteverde, there are many roadways without sidewalks where drivers speed around blind corners, putting any pedestrians walking on the road at risk. This is even more dangerous at night when visibility is limited.

More Reasons to Install Sidewalks...

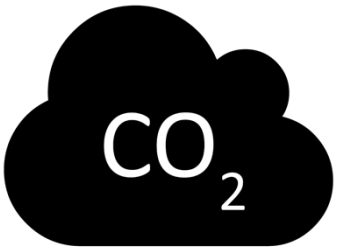
Increased safety of pedestrians

More places for community members to communicate

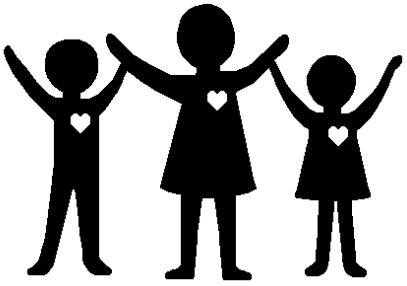
Increased sense of community



Less traffic throughout the town



Less greenhouse gas emissions

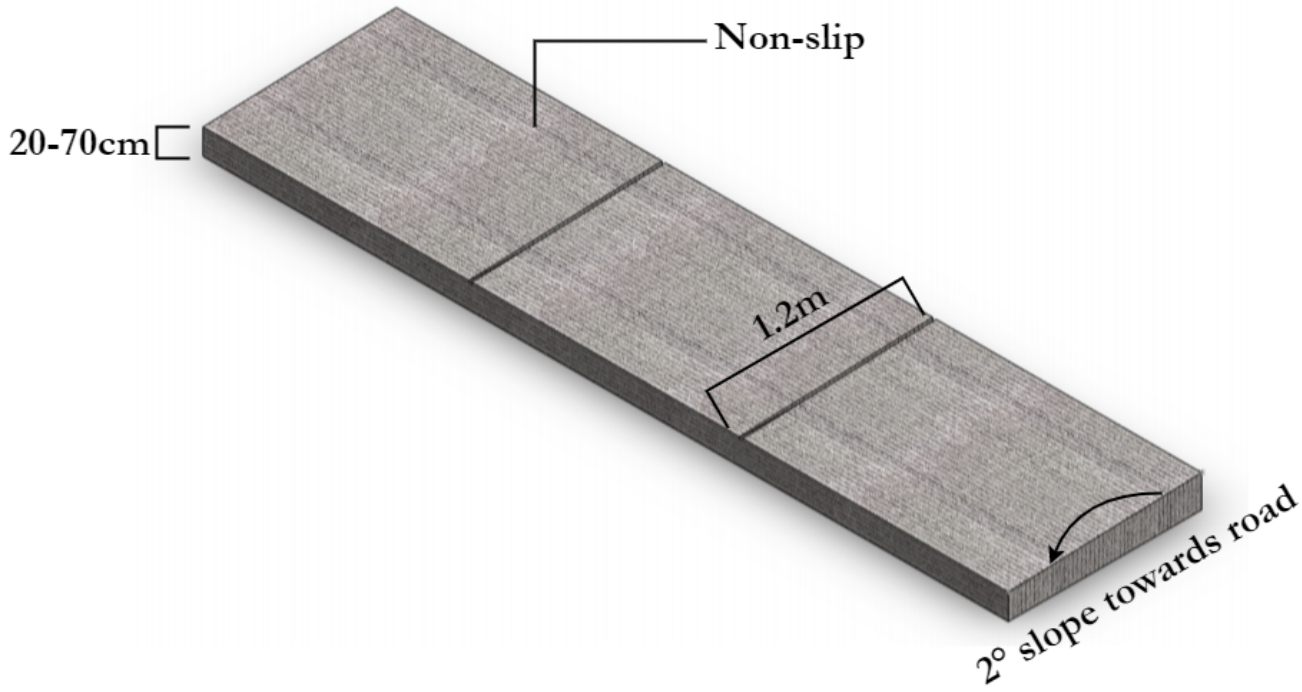


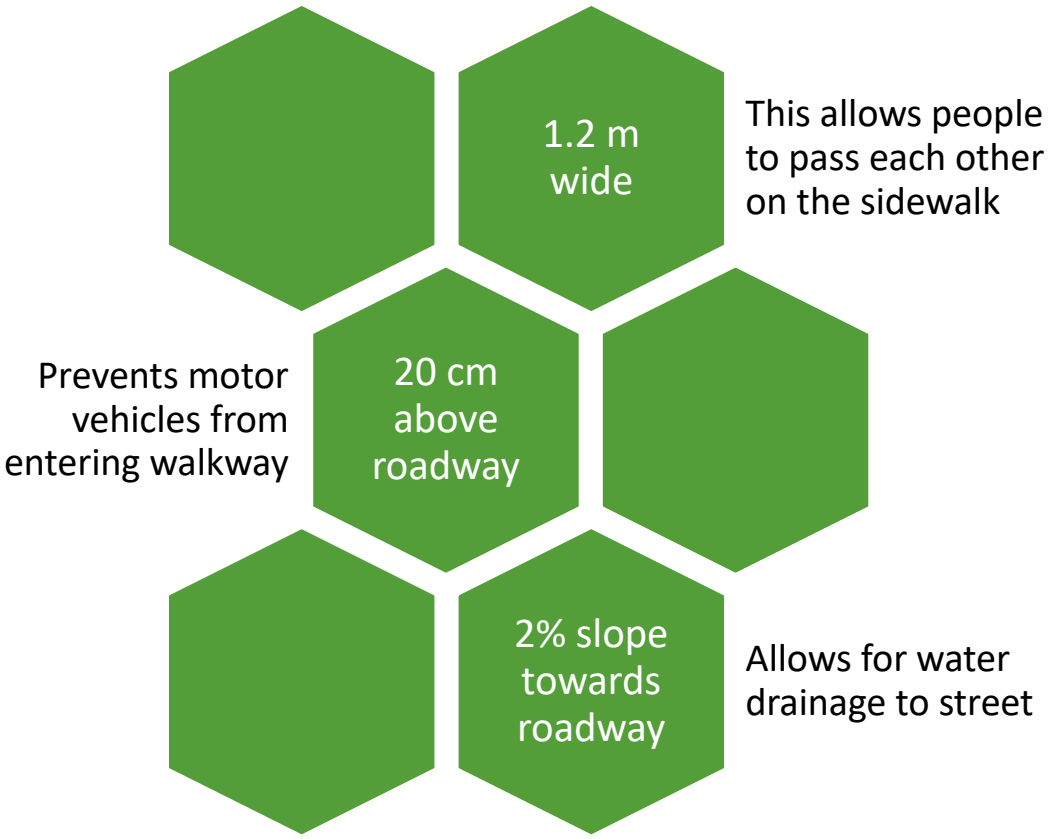
Walking promotes healthier community members

Rules and Regulations

SECTION 2

The Ideal Sidewalk





Other Factors to Consider

STEADY GRADIENT

A steady gradient makes travel along sidewalks easier, especially for people with disabilities.

VEHICULAR ACCESS

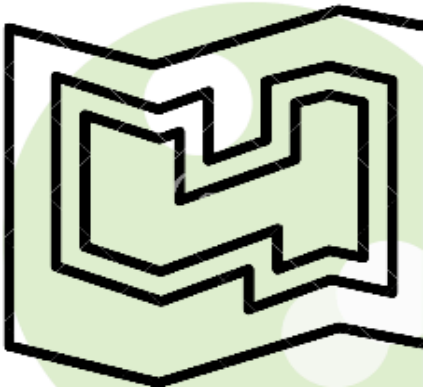
All sidewalks should have a ramp with a maximum slope of 10% on both sides of road or driveway entrances to allow vehicles to cross.

IMPLEMENTATION TIMELINE

Once regulations are passed, landowners will have 2 years to install sidewalks. If they have not been installed within that time line, the Municipality will install them, and the landowner will be charged for material and installation fees.

CONSULTATION

All sidewalk implementation plans MUST be submitted to the Municipality for review before installation.



In Summary, Sidewalks...

- Must be non-slip
- Have at least 20 centimeters of height between the ground and the height of the sidewalk up to a maximum of 70 centimeters
- Talk to engineer for height
- Must be parallel with the road with a gradual or constant gradient
- Must be a minimum of 1.2 meters wide
- Must have a 2% slope towards the street for water drainage
- Must be continuous from an adjacent sidewalk if one exists to the next

Railings are required if:

- The height between the road and the top of the sidewalk is greater than 70 centimeters
- The slope of the sidewalk is greater than 20% and right next to the road or
- There is a 15% slope on one side of the sidewalk

Specifications for railings are as follows:

- They must be 90 centimeters in height above the sidewalk when it acts as a handrail and 110 centimeters to protect the pedestrian from falling (2)
- Must have bars going vertically or diagonally to prevent injury or must include a fence (4)

Drainage

Adequate drainage is needed:

- When there is sewage and asphalt, the water courts that allow water to leave the street to the sewer must be located no more than every 15 meters. The drawers must be at least 10 cm high and 20 cm wide. They must have log boxes where to check the sewer no more than every 50 meters.
- If no road is paved and there is no sewerage, the cuts must leave where there are natural water flows to farms.
- The diameter of the sewer system depends on the volume of water that is emptied on that ditch that depends on the topography, the amount of water that enters, and the length is intended to be tubed.
- If it is on a sewer, the drain below the sidewalk must be at least in diameter and be accessible for regular cleaning. The sewer must be surrounded by stone to keep it in place.
- Grating for sidewalks must be placed in the opposite direction of travel to prevent tripping and getting stuck in the grate. The holes in the grates should be 3 centimeters in length by 1 centimeter in width. The grate should be 1.2 meters in

length by 0.5 meters in width and the height should match the height of the sidewalk. These grates should be cleaned at the same time that the rest of the sidewalk is cleaned.
- There must be a water drainage system next to the sidewalk on the side of the road to allow water flow or it must be underneath and have the ability to be cleaned and maintained on a regular basis

Vehicular Access:

For places where a vehicles need to cross a sidewalk:

- There must be a ramp at a maximum slope of 10% on both sides of the sidewalk to allow the vehicle to cross.
- These ramps must have a slope of 2% on either side in order to allow for proper water drainage.

Expectations of landowners:

- Landowners who border public roads in urban or suburban areas have 2 years to install continuous sidewalks from the announcement of this regulation. Urban areas count at any place in a city and suburban counts as any place within 5 minutes from the city.
- Landowners, neighbors and businesses who benefit from the sidewalk are encouraged to collaborate for construction and maintenance.
- If landowners do not construct the sidewalk according to specifications within two years, the municipality will install it for them. The landowners will be notified a week before construction by the municipality is to begin. The landowners will be charged the cost of installing the sidewalk. This includes fees for materials and labor. They will have one year to pay back the municipality for these charges. If the landowners feel they may not be able to meet this deadline they may prepare a written statement explaining their reasoning in which the municipality will have ten business days to evaluate the request and approve or deny the claim, including the possibility of a monthly payment plan.

Designs and Best Implementation

SECTION 3

What Constitutes a “Good” Sidewalk?

This sidewalk uses materials that can be found locally and has drainage channels.

Stone or brick pavers can be used to construct a sidewalk that is non-slip, easily accessible, and can drain to the road easily.

This concrete is corrugated to prevent slipping and has a drainage ditch on the side to prevent water pooling.

By adding a 2-3 inch space between the sidewalk and the road, maximum drainage to an underground culvert is achieved.

A space between the sidewalk and roadway of at least 20 centimeters keeps cars off the walkway, and allows pedestrians to walk safely.

What About a “Bad” One?

Waffle pattern sidewalks can catch people’s feet as they’re walking, causing them to trip and fall

Although this walkway is off the road and has plenty of greenspace, it is encroaching on the path, making it difficult to walk.

This sidewalk is elevated high off the ground; much higher than the bus in the picture for reference. A pedestrian could easily trip on the bigger rocks or roots in the sidewalk and fall off the ledge, possibly leading to injury.

Large roots in the middle of this elevated sidewalk can cause tripping, and possible injury.

Difficult Construction

Due to past construction in Monteverde, there are quite a few locations where building a sidewalk may prove to be difficult. For example, on the road downhill from Taco Taco and Supercompro, there are large drainage ditches; sidewalks must either be built over the drainage or on landowners property adjacent to it. The drainage ditches and current solutions to the sidewalk issue are seen below.

Sections of ditches are broken up by different types of drainage in many areas. This makes it more difficult to construct a continuous sidewalk.

Some landowners have made strides to create passageways for themselves to access their homes from the roadway, but these options are often unacceptable for widespread use, and cannot be used as a sidewalk design.

The dimensional lumbar used above may work for the few passersby that live close by, but would be a hazard if used for a sidewalk that has more foot traffic.

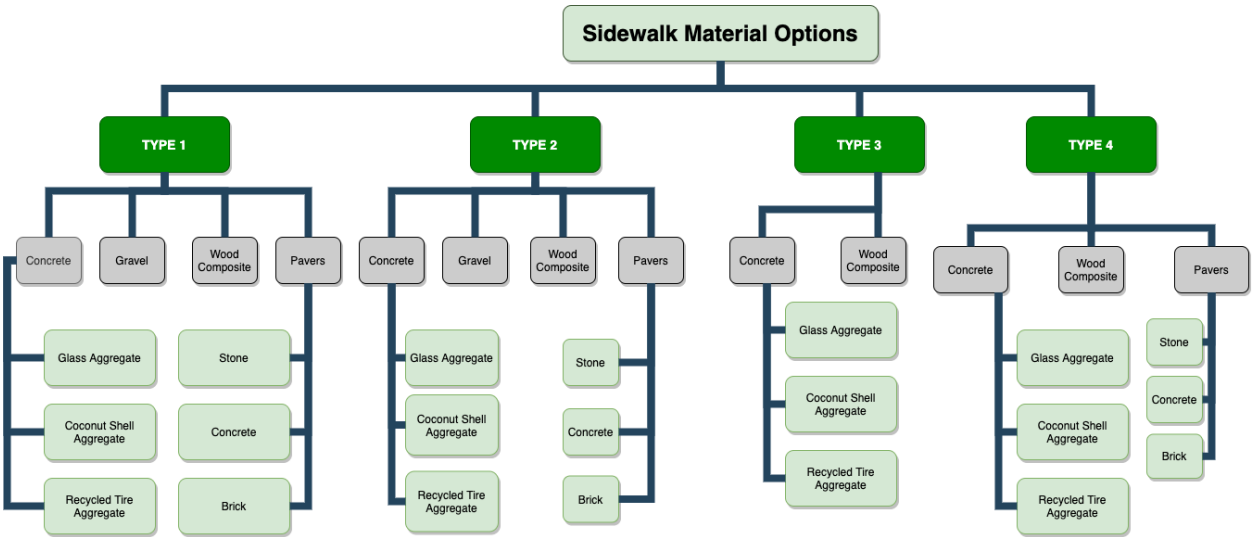
Filling over a tube with gravel can easily wash out. In addition to this, it is impossible to create a continuous sidewalk with gravel in this area, as you cannot fill in the drainage channels abutting the tube seen above.

Although many places along this stretch of road need to rethink their current sidewalk design, or begin considering it, there are a few locations with designs that are perfect for the road conditions. Examples can be seen below.

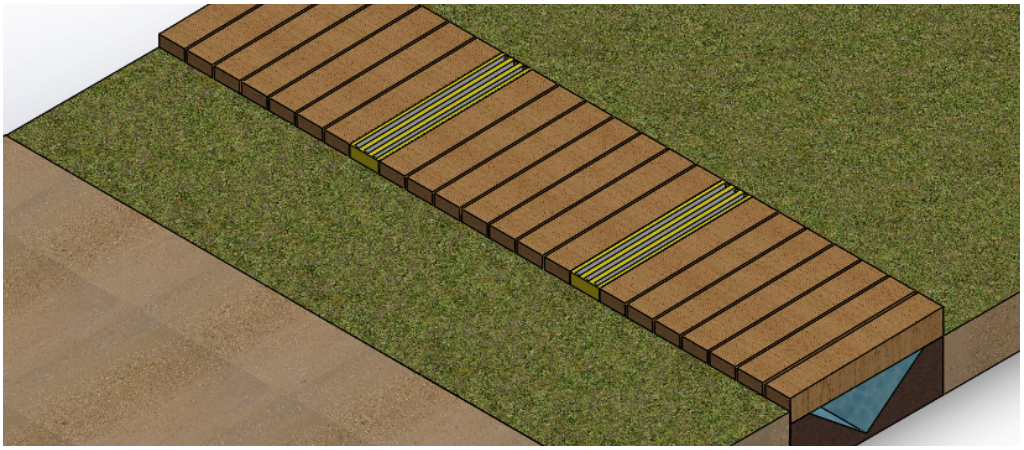
Currently, this section of sidewalk is only large enough for a car to pass over, and is used more as a driveway than a sidewalk. This design, if expanded, could be exactly what is needed in this location.

A local business along this stretch of road is in the process of installing a sidewalk network up to Taco Taco. This sidewalk sits over the drainage culvert, which allows for drainage from the road and the sidewalk itself underneath it.

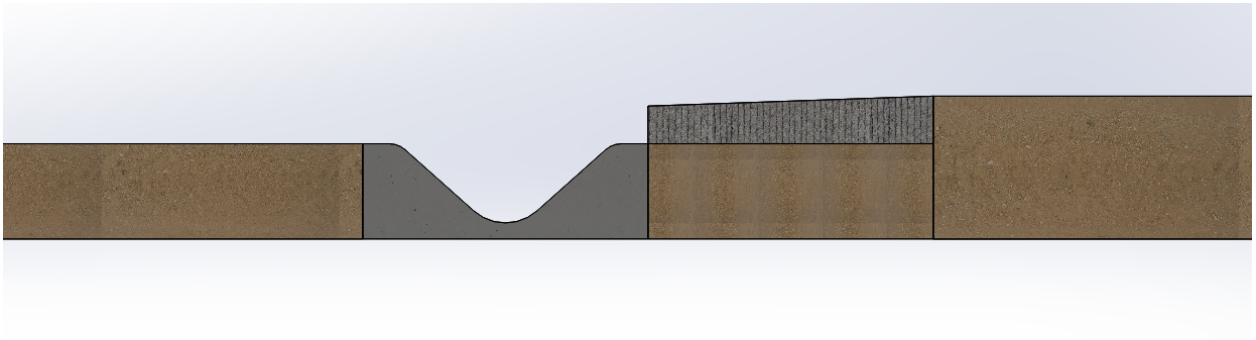
How to Choose What Design Suits You



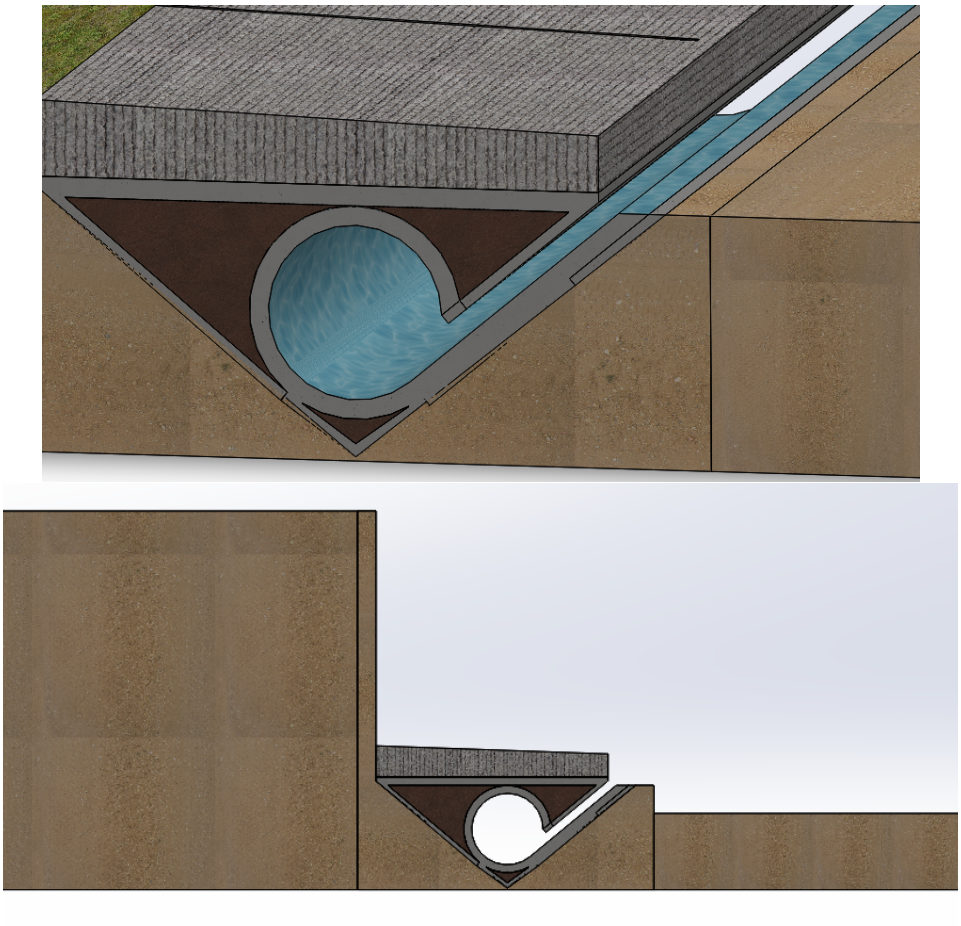
Type 1: Sidewalk with Green Space



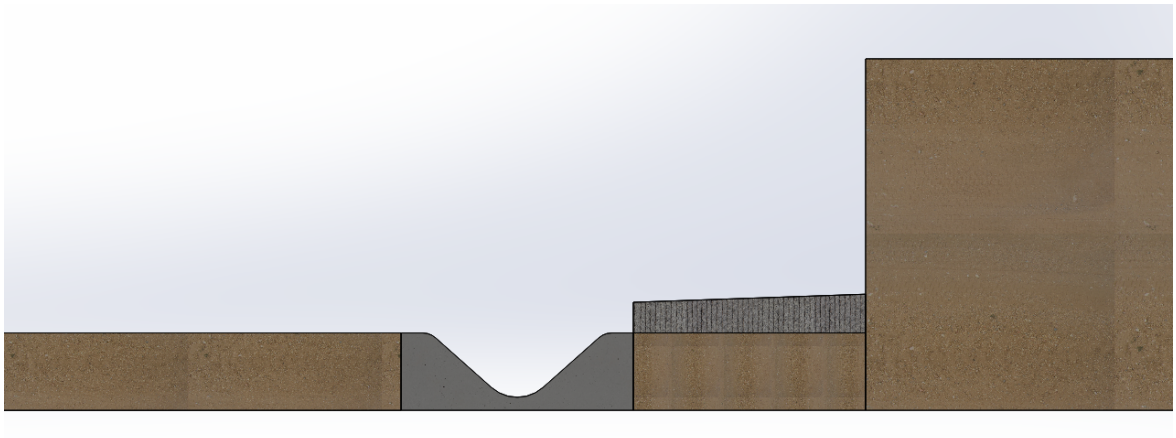
Type 2: Sidewalk Directly Adjacent to Culvert



Type 3: Sidewalk Over Culvert



Type 4: Sidewalk Between Drop-Off and Culvert



Design Group 1

In Monteverde, there are many locations where there are water drainage ditches on the side of the road where sidewalks should be present. In many instances, there are also large drop offs or houses built close to the road on the other side of the drainage pit, which makes it necessary to construct the sidewalk on top of the drainage. Design Group 1 contains designs that can be implemented above water drainage culverts. The installation specifics for all Group A designs are the same.

All designs listed below show the dimensions for the sidewalk. All examples in Design Group 1 allow for drainage to a ditch located beneath the sidewalk. For each design, there are .15 meters of earth below each side of the sidewalk to support it. Each design is a one way, simply supported span. For installation, it is important to ensure there are at least two inches of compacted subgrade, followed by two inches of crushed surfacing top course (CSTC), and finally topped by the desired sidewalk material, as seen below.

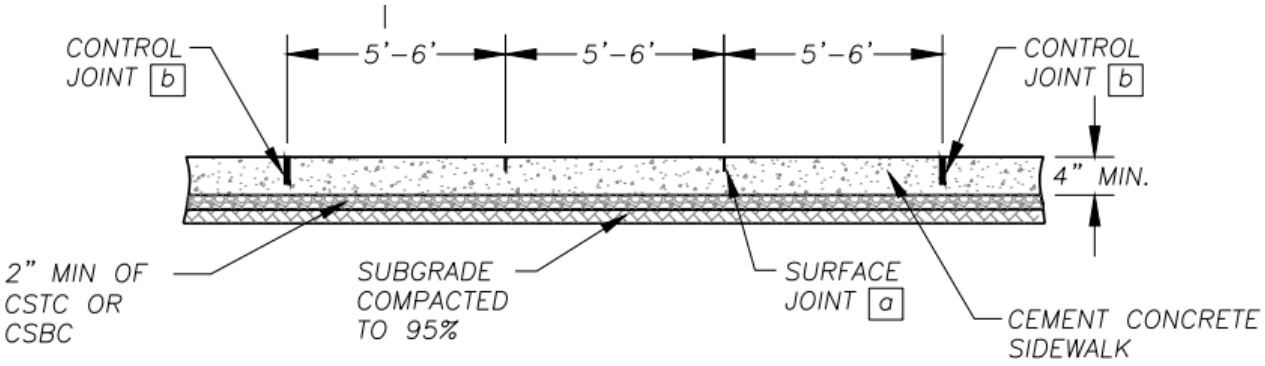
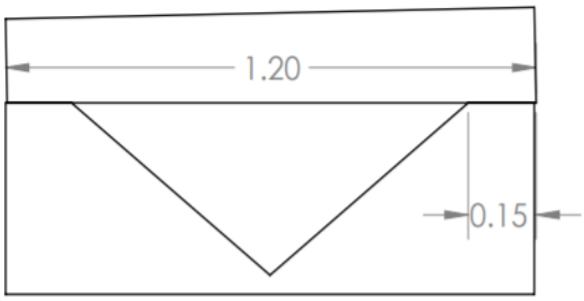
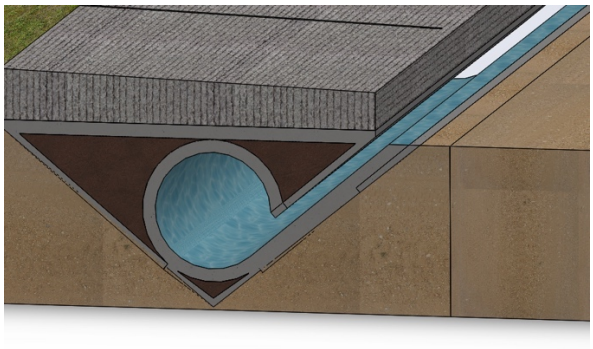


Figure 1: Installation requirements for a sidewalk (Standard Details, 2019)





Figures 2 & 3: Design specifications for a sidewalk over a culvert.

Step-by-Step Concrete Installation

Step 1: Investigating Ground Conditions

Begin designing your sidewalk by determining the ground conditions you will be constructing on. If you are working with sandy soil, there is only need for removal of topsoil and sod (The Family Handyman, 2019). If you are building on top of clay or loam soil, it is necessary to remove enough soil to allow for an 8 inch layer of compacted subgrade gravel. All bottom soil should be compacted to create a flat base, then 2-4 inches of gravel subgrade or crushed surfacing top course should be poured on top and also compacted (DIY Network, 2015). If the sidewalk is going to installed over a drainage ditch, complete these steps over .15 meters of ground on each supporting side. If being installed over concrete lined drainage ditches, this step is unnecessary.

Figure 4: Example of crushed surfacing top course (Construction, n.d.)

Step 2: Framework and Slab Creation

Option 1: Installing Framework

If your concrete sidewalk is going to be poured directly into place (i.e. not over a drainage ditch), then the frame of the sidewalk should be mapped out using 1 inch x 4 inch x 5.5 foot boards. Wooden stakes should be placed every 5.5 feet, and the boards

should be attached to said stakes with screws. It is important to ensure form boards are level. Stakes should sit below the top of the siding. Siding boards should be braced, so as not to move when concrete is poured.

Figure 5: Bracing for siding boards (Better Homes & Gardens, n.d.)

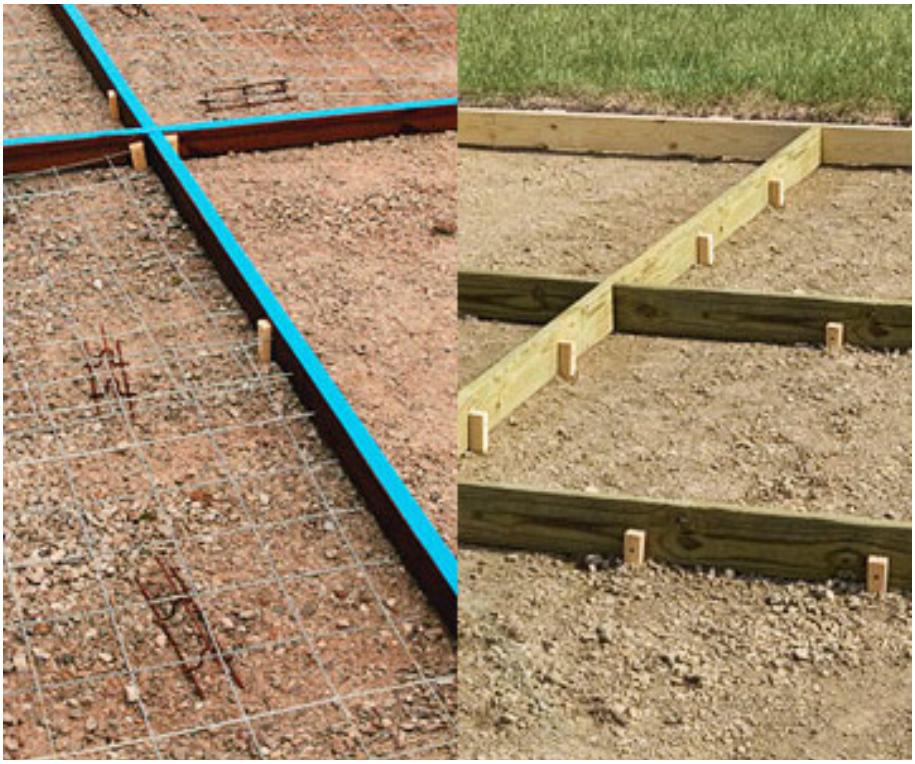


Figure 6: Multiple sections of staked siding boards before concrete has been poured (Better Homes & Gardens, n.d.)

Option 2: Creating Pre-Cast Concrete Slabs for Installation Over Drainage

In order to create pre-cast concrete slabs, it is necessary to make a concrete mold that can be reused for each individual slab. Rubber mold making kits can be bought and used to make the molds. To begin, wooden framework must be set up in an area larger than the desired size of the slab, as seen in Figure _.

Figure 7: Framework for making a rubber mold of a stone (Polytek Development Corp., n.d.)

Once the framework has been designed and secured, the framework for the slab itself needs to be created. This can be done many ways, the easiest likely being creating a box with one open face the exact size the sidewalk slab needs to be. Any cracks in the box should be sealed with caulk or other binding material to prevent the rubber solution from seeping into the open space of the box. This box can be placed inside the larger framework, open side down, and rubber can be poured over the top, covering the hollow wooden box. Once the rubber solution dries, the wooden box can be removed, and you have a mold that can be used to create identical concrete sidewalk panels.

Figure 8: Finished rubber mold of stone to be used for pathway installation (Ploytek Development Corp., n.d.)

Step 3: Mixing Concrete

Once framework or molds have been created, it is time to mix the actual concrete. Concrete can be made according to the directions found on the bag. Alternative aggregates can be used if desired; more information on this can be found in Section 4 of this manual under “Materials”.

Step 4: Pouring Concrete

Once concrete has been poured either into the framework (Option 1) or mold (Option 2), it must be leveled. Dragging a 2 x 4 inch board across the surface of the concrete after pouring allows for basic leveling. This should be further smoothed by using a concrete float.


Figure 9: Concrete float being used to smooth concrete (Suryakanta, 2014).

Step 5: Finalizing the Design

After the concrete has set for about an hour, a trowel should be used to separate the edge of the concrete from the framework (Option 1), or from the rubber mold (Option 2). Every 5.5 feet, a straight edge should be used to create expansion joints, which will allow the concrete to expand without cracking. Finally, a broom can be dragged across the surface of each lightly to corrugate it, creating a non-slip surface.

Figure 10: A non-slip surface on a sidewalk in Monteverde located between CASEM and Hotel Belmar.

Design 1.a: Concrete with Roadside Drainage Holes

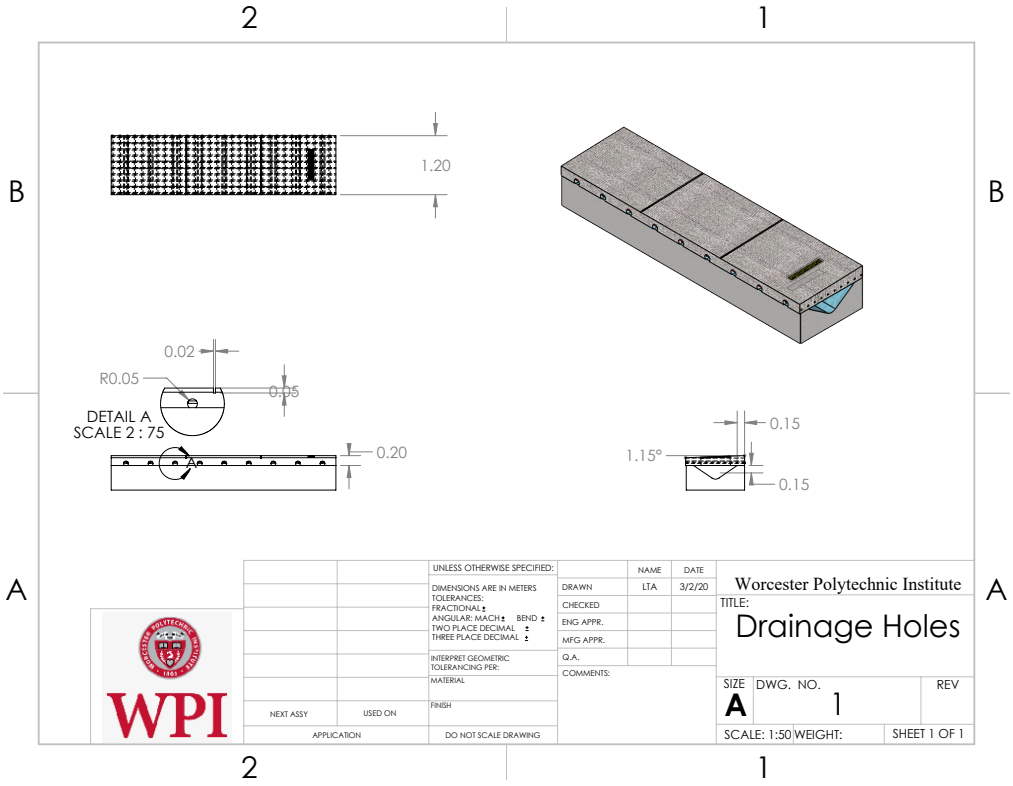


Figure 11: Installation specifications for Design 1.a.

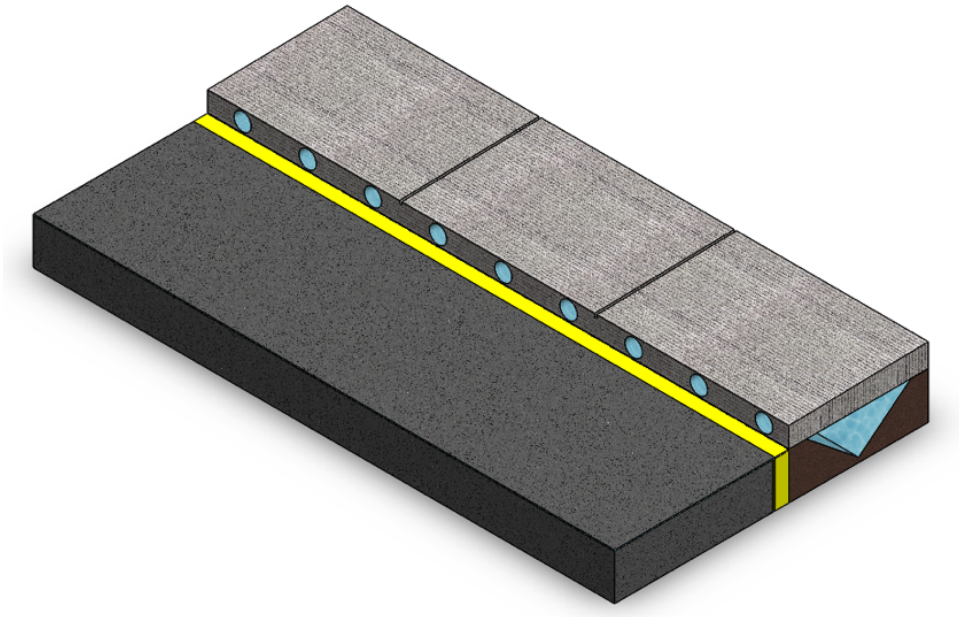


Figure 12: Design 1.a pictured as applied with culvert visible.

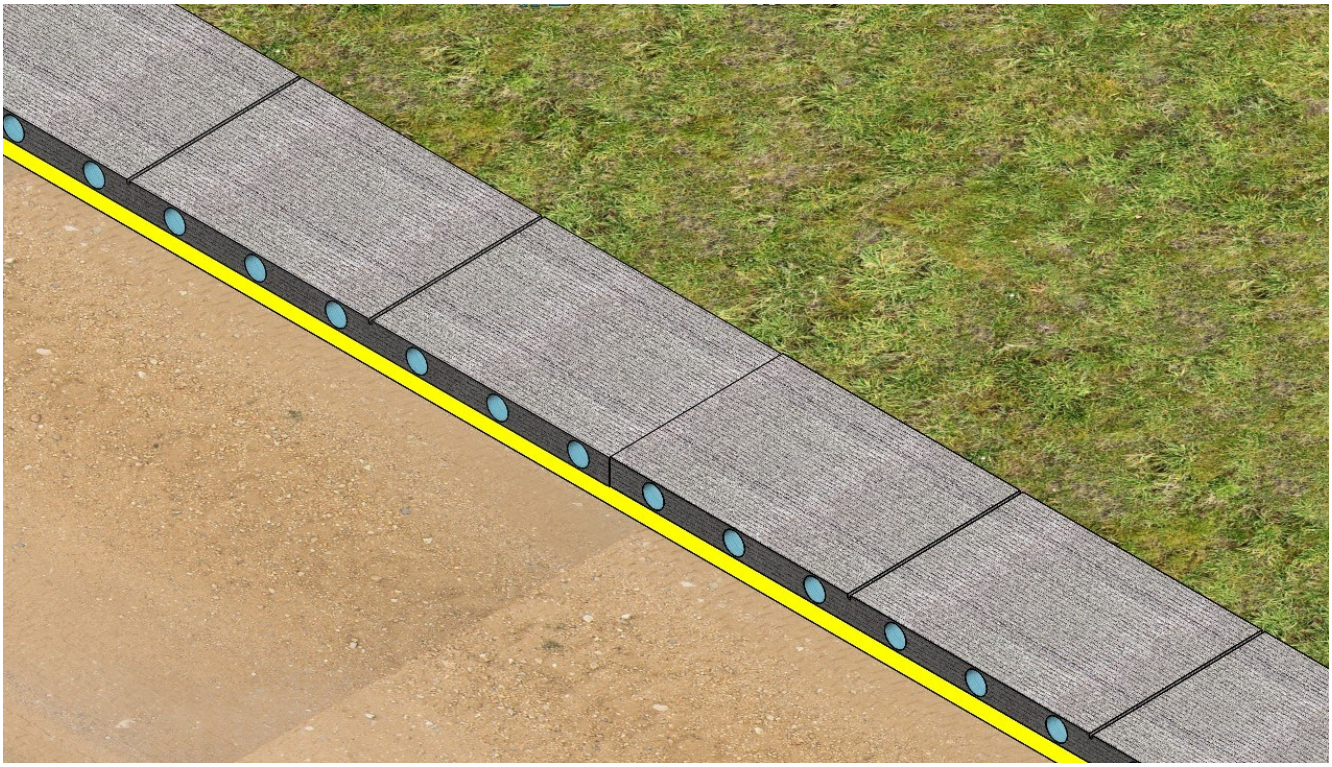


Figure 13: Design 1.a pictured as applied near a roadway.

Design 1.a includes multiple drainage passageways from the road to the culvert beneath the sidewalk. The sidewalk is made of concrete with a corrugated surface for slip prevention. It is tilted 2% towards the roadway so water does not pool on top of it. This option is accessible to individuals who may require the use of a wheelchair or other mobility devices, and can use alternative aggregates such as recycled glass, rubber, and coconut shells to decrease its carbon footprint. The last image depicts how this design will look once installed.

Design 1.b: Concrete with Drainage Slits

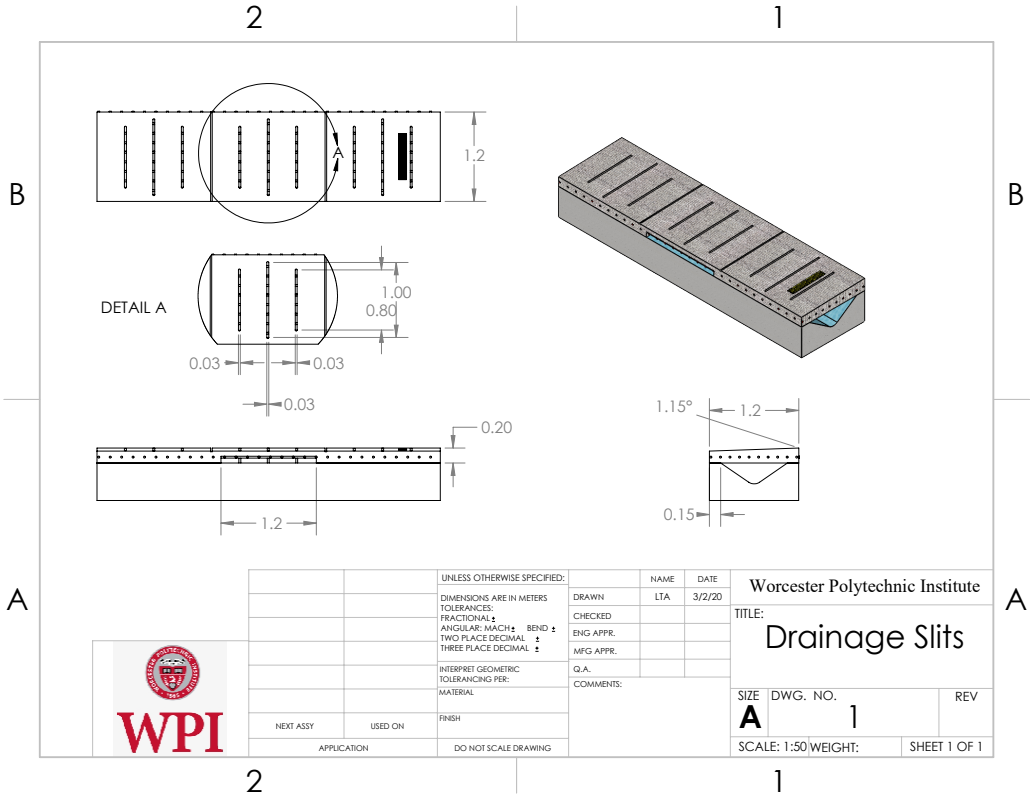


Figure 14: Installation specifications for Design 1.b.

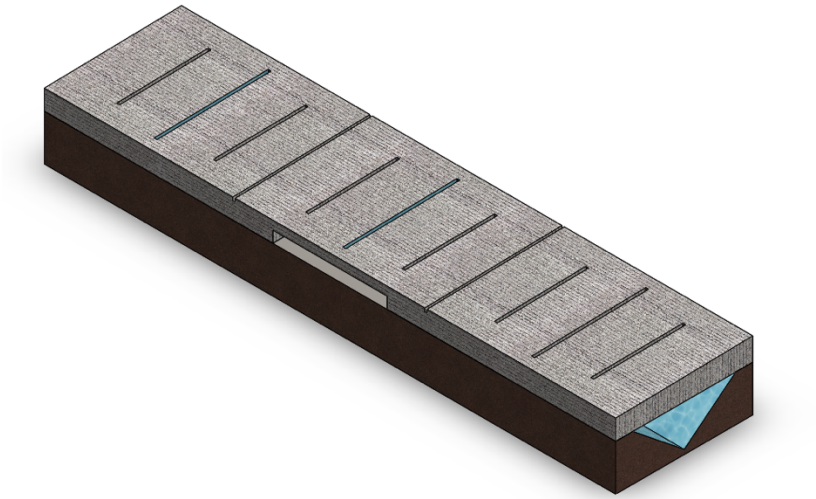


Figure 15: Design 1.b pictured as applied near a roadway with culvert visible.

Design 1.b also uses concrete, and can be modified to be more environmentally friendly. The inclusion of .03 meter slits on top of the sidewalk allow for drainage to the culvert below. In addition to this, there is an open section that allows for drainage from the roadway to the culvert below. This design is also useful for individuals with disabilities, and allows for even more drainage than the aforementioned design.

Design 1.c: Wood-Composite with Drainage Grates

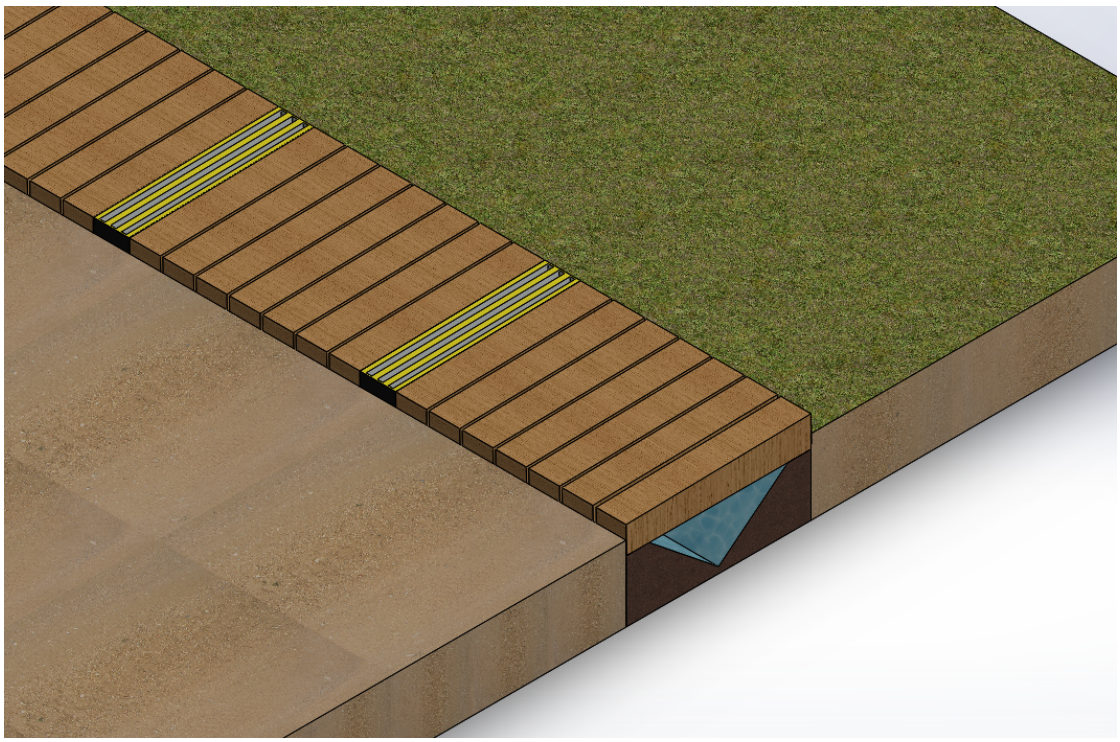


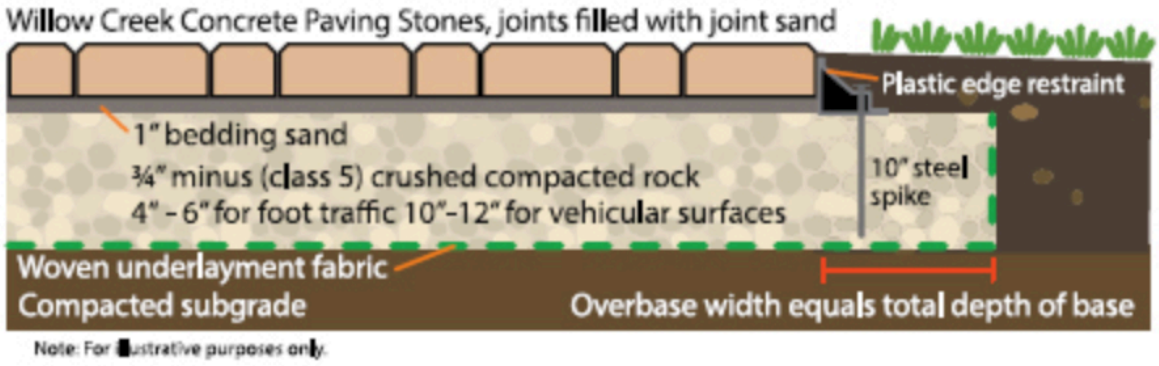
Figure 16: Design 1.c pictured as applied near a roadway with culvert visible.

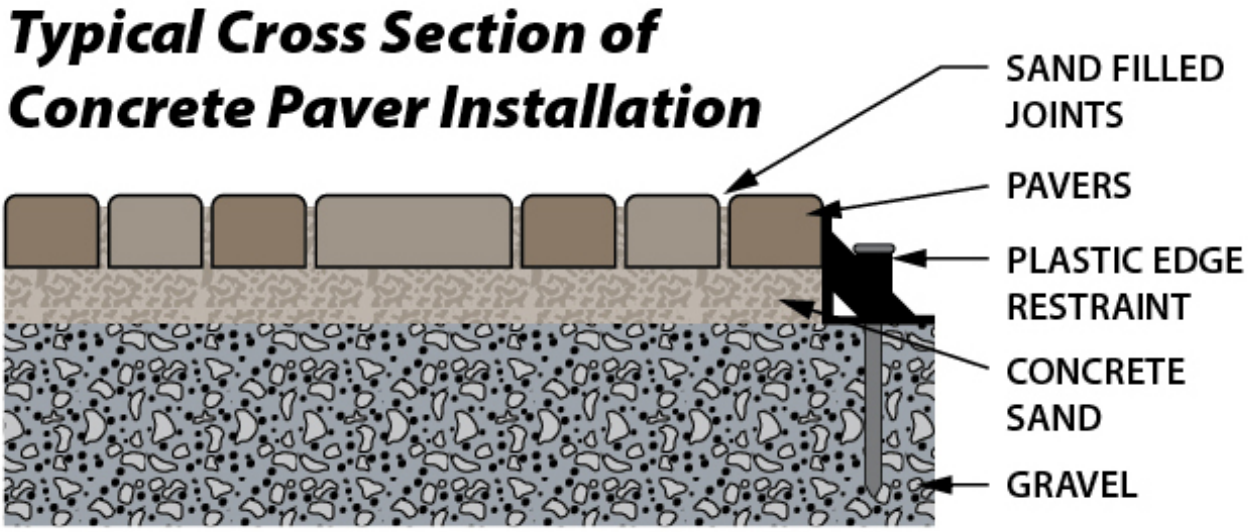
Design 1.c uses a combination of wood-plastic composite for the main sidewalk and metal for grates. Wood-plastic composite is used as opposed to plain hardwood as it lasts longer, especially in a location like Monteverde, where it is wet and rainy most of the year. Hardwoods will inevitably rot after just a few years, causing a need for constant maintenance or replacement soon after installation. By using a wood-plastic composite, repair costs are kept to a minimum, and lifespan is increased. Metal grates every __ feet allows for additional drainage to the culvert below the sidewalk. Grates can be removed for cleaning of the culvert.

Design Group 2

Although there are many locations in Monteverde that require design over culverts, there are also many locations that do not. In these places, it is more feasible to design a typical sidewalk. Designs 1a-c can be designed as a normal sidewalk over ground still using Figure __ as a reference for amount and type of subgrade to use.

An alternative to using typical concrete is to use stone or brick pavers to design a sidewalk. Some benefits of using stone or brick pavers is increased permeability, less of a chance of cracking, and easier maintenance and repairs. Permeable stone and brick pavers have different installation requirements than concrete, which can be found below in Figures 17 & 18.





Figures 17 & 18: Examples of ways to install stone pavers (Western Interlock Inc., 2016; Willow Creek, n.d.)

Step-by-Step Paver Installation

Step 1: Excavation

Similar to the concrete installation methods outlined in the Design Group 1:Installation Section, it is important to evaluate the type of earth you will be constructing the sidewalk on. Since the pavers will be supporting foot traffic, there should be about 6-8 inches left for a compacted base below the bedding sand and pavers themselves (Willow Creek, n.d.). Clay or silt should have woven underlay installed above the compact subgrade layer to prevent the base from weakening, as seen in Figure _. The 6-8 inches of subgrade above the woven layer should be damp, and compacted in 4 inch sections, starting at the edges. Wooden stakes should be installed so their top is level with the top of the aggregate base material.

Step 2: Edge Restraints

Edge restraints should be installed on top of the aggregate base, initially only on one side, to prevent the paver sections from shifting. Screed rails should be installed on top of the wooden stakes, as seen in Figure_. Rails should be level with each other. Spikes should be driven into restraint sections to hold them in place.

Figure 19: Screed rails used in paver installation (Willow Creek, n.d.)

Step 3: Creating the Sand Bed

After installing edge restraints, sand should be spread around the bed where the pavers are to be installed. Sand should then be leveled using some type of straight edge, and the screeding rails should then be removed.

Step 4: Paver Installation

Paver installation should begin along the longest straight section of sidewalk. It is also recommended to work uphill as opposed to downhill. Once all pavers are installed, the second sides' edge restraint should be installed. The surface should then be swept, and passed over with a plate compactor. Final leveling can then be completed. More dry sand should then be poured over the top of the pavers, and swept into cracks using a broom to fill in any small gaps still left as seen in Figure _. It should then be passed over again by a plate compactor. A sealant can be applied if desired to stabilize joint sand or preserve pavers.

Figure 20: Application of joint sand to installed pavers (Willow Creek, n.d.)

Design 2.a: Permeable Pavers

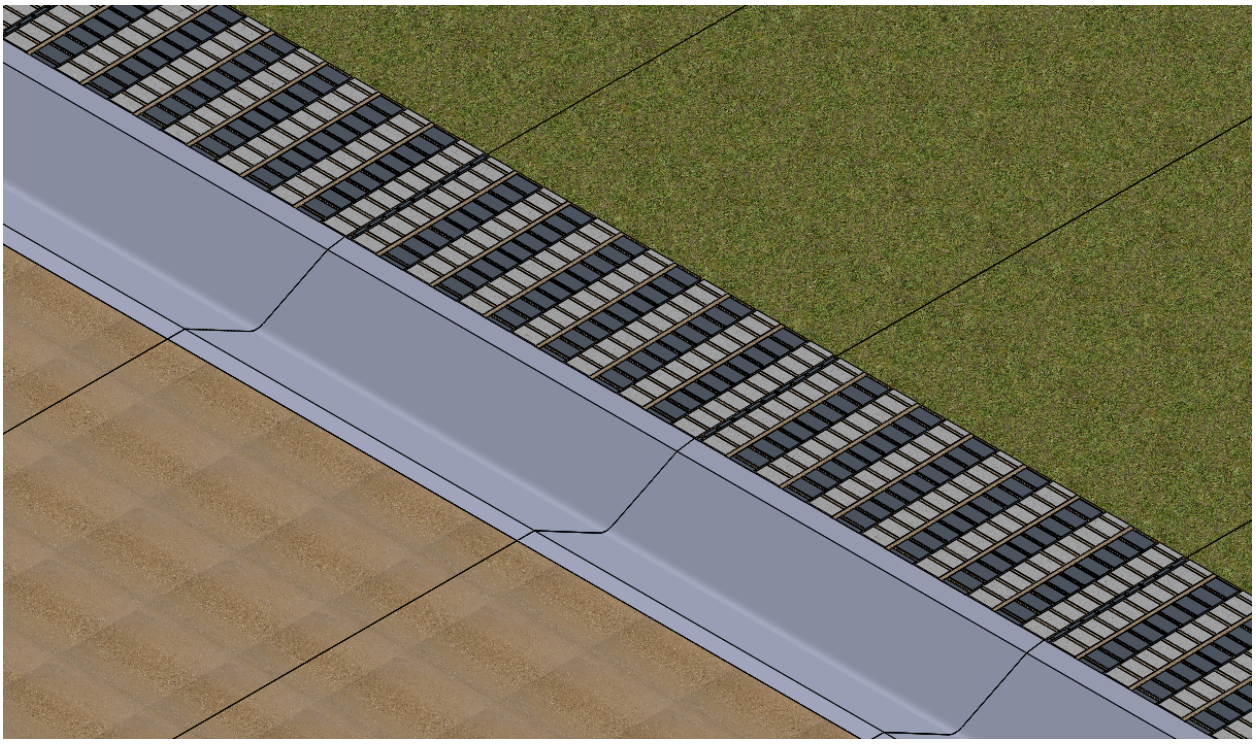


Figure 21: Design 2.a pictured as applied near a roadway with adjacent culvert.

Figure 22: Design 2.a as installed with areas for permeation.

Figure 23: Example of permeable stone pavers (Stewart, 2017).

There are many different ways to install typical permeable stone pavers, and many different designs they can be installed in. The first example shows a method in which there is small space between uneven stones to allow for increased permeability. The last example shows diamond shaped permeable spaces. Increasing permeability in the sidewalk itself to the ground increases percolation of water through the ground, which decreases the amount of water that goes straight into the drainage system. It is a way to help keep the natural water cycle viable and active. This design is easy for people with disabilities to travel on, and easier to fix than concrete slabs.

Design Group 3

Group 3 includes designs that utilize wood-plastic composites, which have a longer lifespan than regular hardwood. Wood composite designs increase permeability, much like the stone or brick paver designs, and allow for water to cycle through the natural environment, as opposed to ending up in a drainage culvert. Installation methods for both designs in Group 3 are different, and will be assessed after each design is introduced.

Design 3.a: Wood-Composite

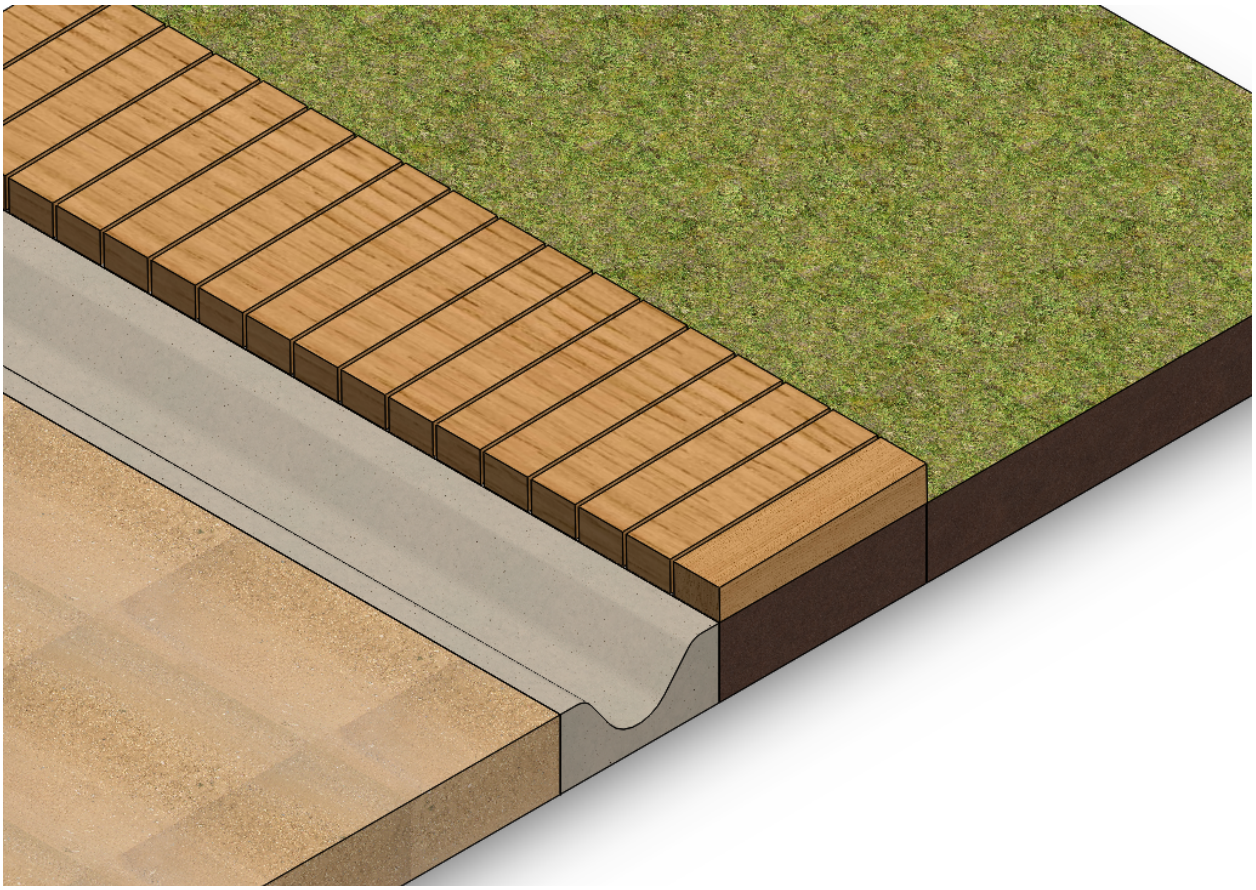


Figure 24: Design 2.a pictured as applied near a roadway with adjacent culvert.

Design 3.a utilizes wood-plastic composite for construction. Small spaces between individual wood panels allows for permeability through the natural water cycle. In addition to this, a 2% slope towards an adjacent drainage culvert is necessary to drain all water from the sidewalk to prevent water pooling. This sidewalk can be installed similarly to sidewalks in the Design 1 Group, following the same compacted subgrade specifications (Step 1).

Design 3.b: Gravel With Wood-Composite

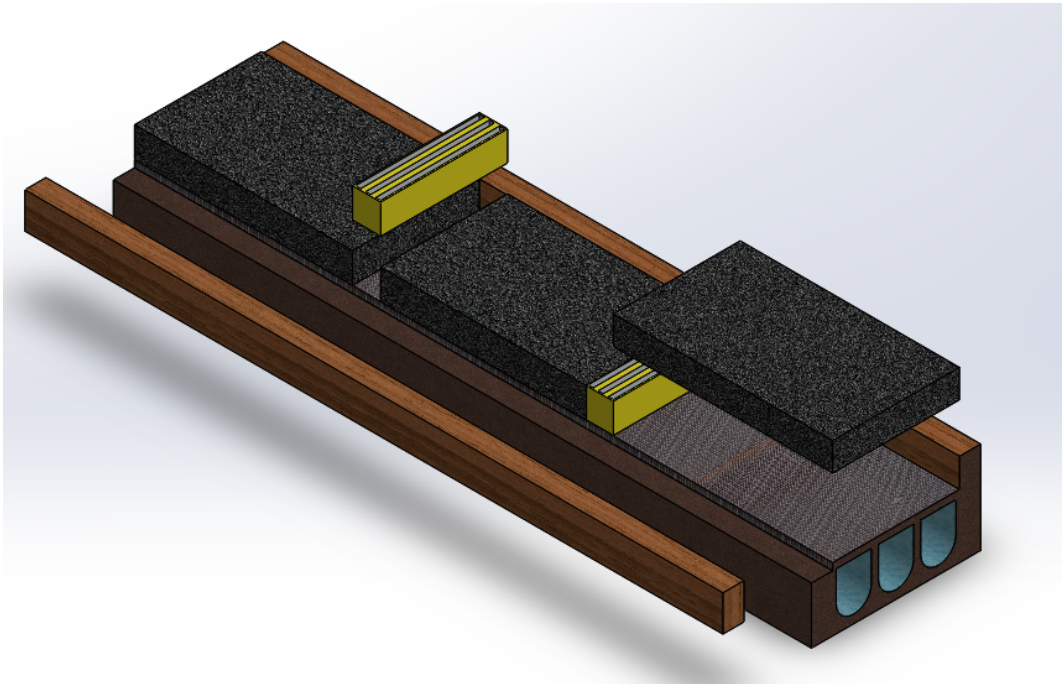


Figure 25: Design 3.b in exploded view.

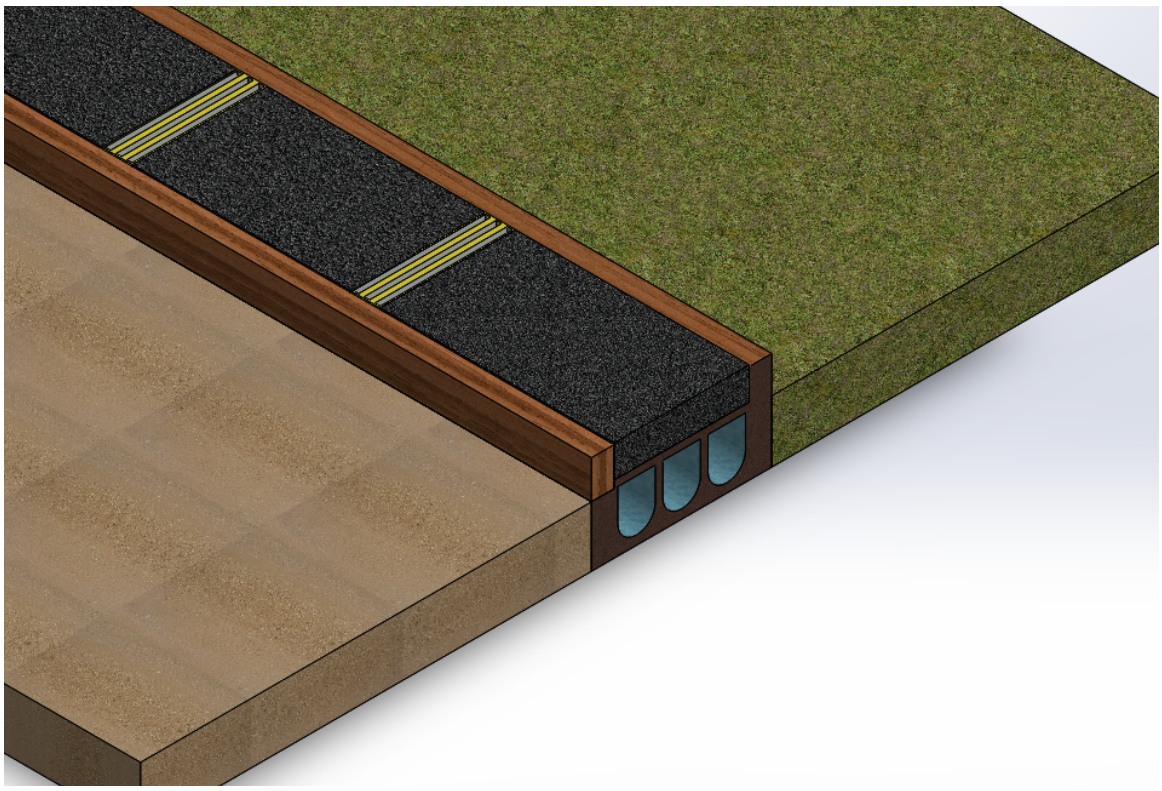


Figure 26: Design 2.a pictured as applied near a roadway with drainage underneath.

Design 3.b uses gravel and wood-plastic composite to create a sidewalk network. Basic permeability is possible through the gravel itself, which drains to U-shaped PVC pipes below, separated from gravel by a layer of mesh. Metal grates dispersed along the length of the sidewalk allow for larger areas of permeability, which also drains to PVC pipes below. This design has a low environmental impact factor and blends in well with the surrounding environment, but poses issues in terms of accessibility. In addition to this, because of heavy rains, there is the potential that the gravel could wash out easily.

Design 3.b Installation

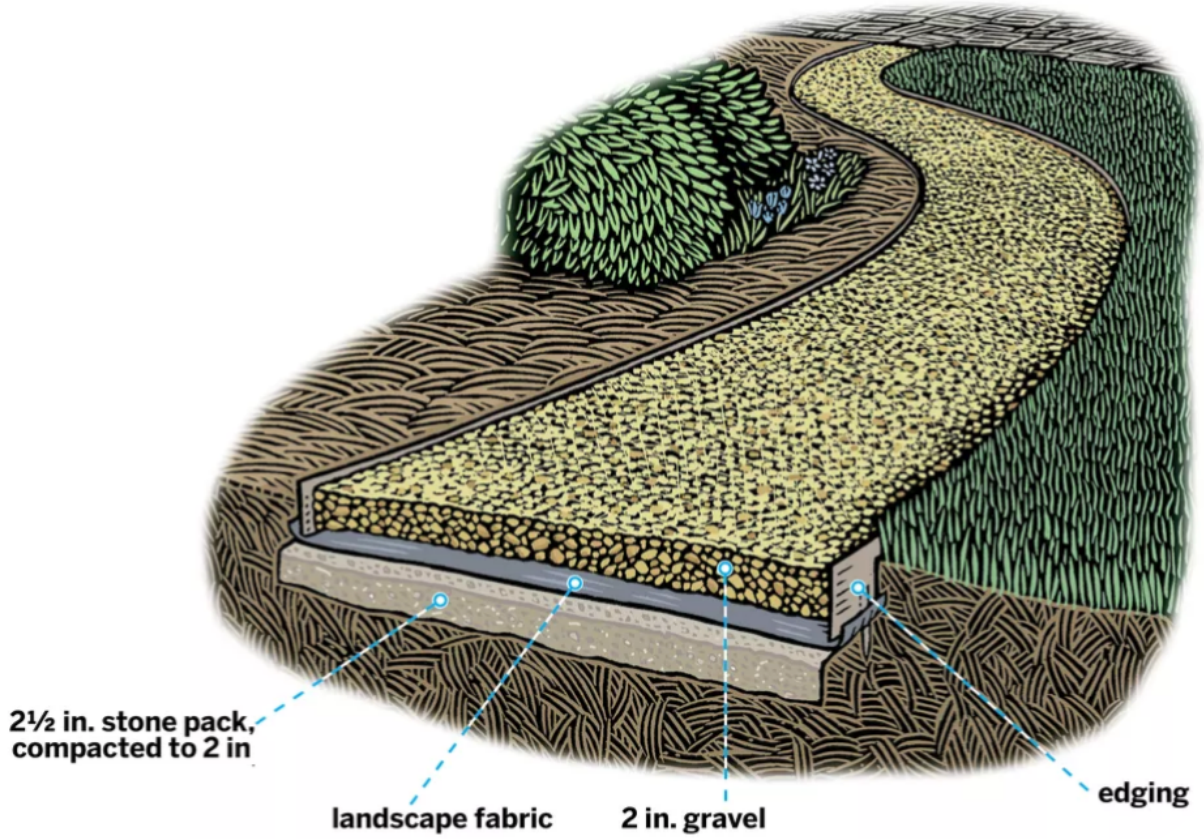


Figure 27: Basic installation of a gravel walkway (Bandon, 2007)

Step 1: Defining Path Edges

To start installing the gravel pathway, the area in which it is going to be installed must be excavated. About 6 inches of dirt should be removed. The bottom layer of soil should be compacted the same as Design Groups 1 and 2 were.

Step 2: Installing the Stone Base

Once the base layer of soil has been compacted, the stone base can be layered over it (Bandon, 2007). The U-shaped PVC pipes should be placed in this layer of subgrade – trenches should be dug, with the pipes lain in them. This layer should be around 4 inches deep. The stone base should then be compacted the same way as the previous subgrade layer was, seen in Figure _.

Figure 28: Compacted subgrade stone layer (Bandon, 2007).

Step 3: Fabric and Edging

After the stone layer has been compacted, landscaping fabric or other type of mesh should be lain over the PVC pipes and compacted layer. Use a pre-measured block of wood to install wooden spikes through the mesh at the same length parallel from each other at even intervals along the length of the sidewalk, as seen in Figure _. Edging should then be installed over the fabric, between the wood spikes and edge of dirt excavated. Ensure that the wood-composite edging sits at least 2-4 inches above the level of the surrounding land, so as to create a raised barrier between the gravel and the land. Wood-composite barriers for metal grates should also be installed as many times as necessary throughout the sidewalk section, following the method laid out in Figure_.

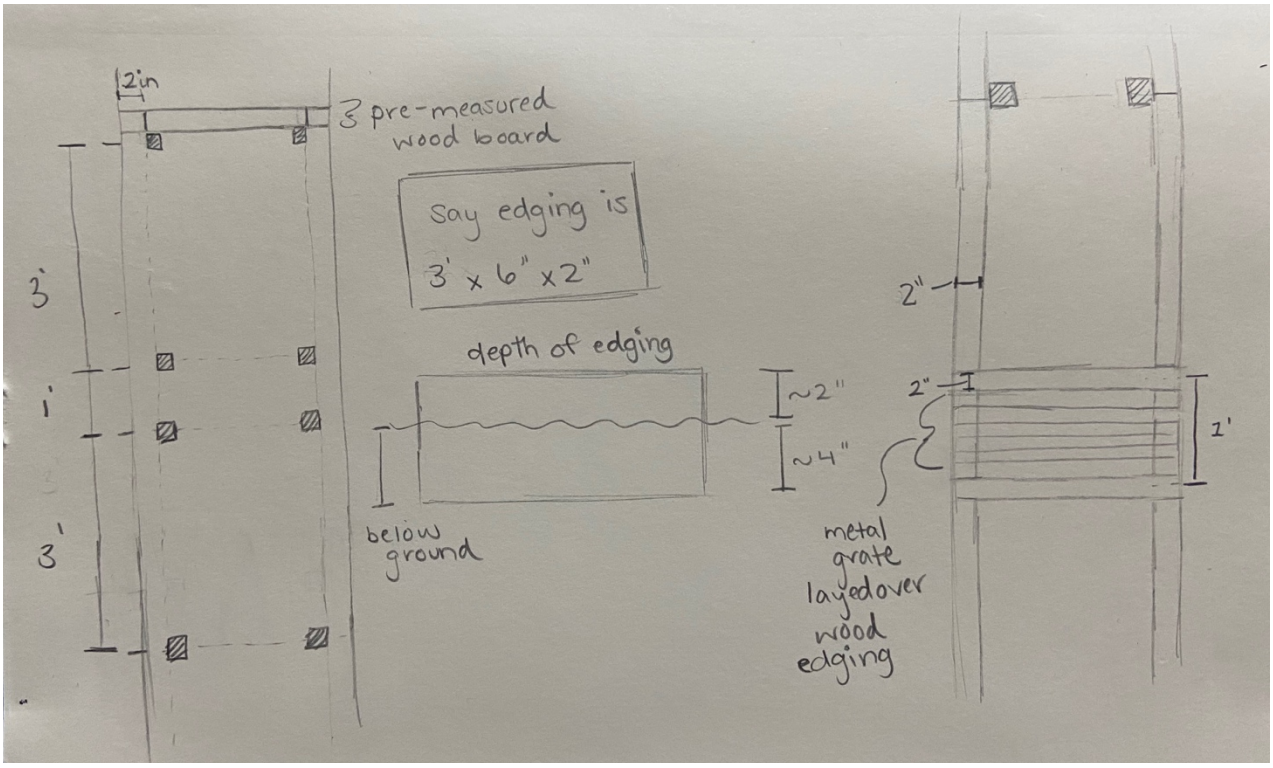


Figure 29: Installation of gravel and wood-composite sidewalk.

Step 4: Gravel Pouring

Finally, a two inch layer of gravel should be poured on top of the mesh. Size of gravel is up to landowners, but it should be noted that larger gravel size prevents wash out but poses issues to accessibility, while smaller gravel size increases chance of wash out, but is easier to travel on.

Other Considerations

SECTION 4

Materials

Concrete Modification

Although concrete in and of itself is not the most environmentally friendly material, working with alternative aggregates, such as recycled glass, rubber, or agricultural waste reduces the greenhouse gas emission greatly. Using recycled glass greatly increases durability factors of concrete, such as denser microstructure and better absorption, which ultimately leads to greater strength over time (Nassar, 2012). Recycled crumb rubber serves to decrease the weight, but also decreases the compressive and flexural strength (Bani-Hani, 2015). Agricultural waste, such as coconut shells, are also an aggregate that can be used to create durable light-weight concrete (Shafigh, 2014). Additional studies found that coconut shell aggregate had higher water absorption rates, developed more compressive strength over time, and resisted biological decay over a one year study period (Gunasekaran, 2012). Overall, compressive strength of concrete decreases as the percentage of coconut shell in the mixture increases (Sonawane, 2016). Although each aggregate has its own set of benefits, it seems as though recycled glass may be the best solution, with coconut shell aggregate being the second best. Although glass aggregate has a lower absorption rate, a 2% slope towards the road, leading to a gutter system, will displace any water that would otherwise pool atop the sidewalk. Examples of aggregates can be found below.

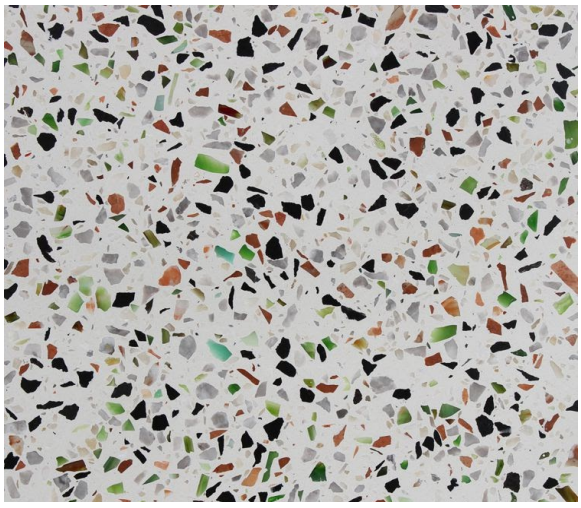


Figure 30: Recycled glass used for aggregate in concrete (Recycled Glass…, n.d.).

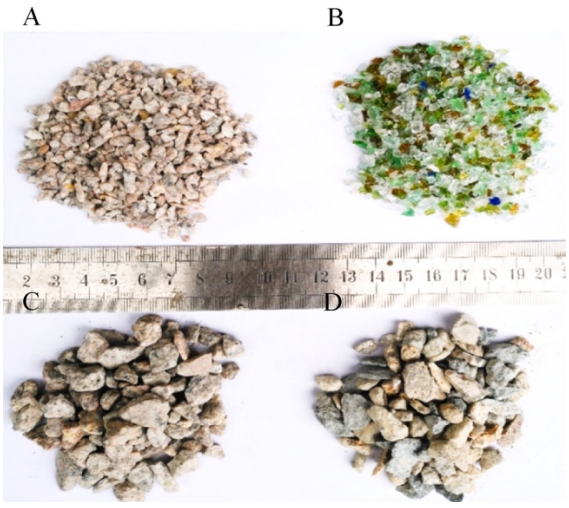


Figure 31: Size differences between fine (above) and coarse (below) aggregates (Chandratilake, 2012).

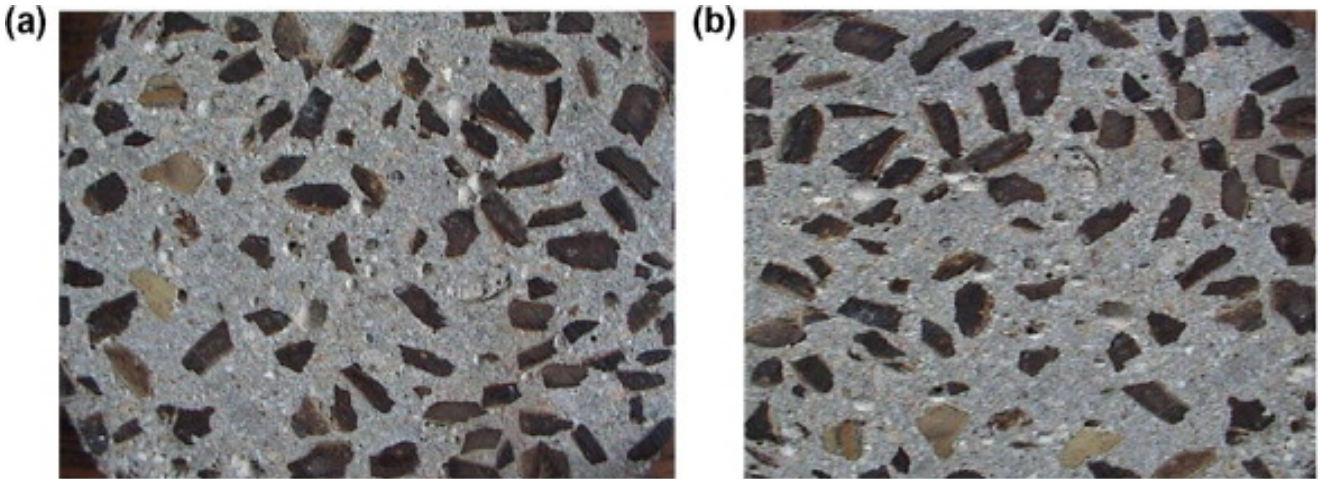


Figure 32: Coconut shells used as coarse aggregate in a concrete sidewalk (Shafigh, 2014).

Glass Aggregate:

When used to replace up to 25% of ***coarse*** aggregate

Pros:	**Cons:**
Repurposing a common waste item in Costa Rica	The structural strength of the concrete is less than that of glass when used as a fine aggregate
Higher permeability which leads to less runoff	

When used to replace up to 25% of the ***fine*** aggregate

Pros:	**Cons:**
Repurposing a common waste item in Costa Rica	Less permeability than coarse glass aggregate which will lead to runoff
Structurally stronger than the coarse glass aggregate	

Coconut Shell Aggregate:

When used as fine or coarse aggregate:

Pros:	**Cons:**
Abundant in Costa Rica	As a biomaterial, it will decompose over time, requiring that it be replaced often
Created naturally, will not produce any environmental contaminants	

Crumb Rubber Aggregate:

When used as fine or coarse aggregate:

Pros:	Cons:
Removes rubber from landfills	Can leach microplastics into the water supply when the rubber degrades
	Decreases the strength of the concrete when it replaces more than 20% of the aggregate (fine or course)

Using Plastics and Plastic-Based Materials

Although wood-plastic composites, which are suggested for use in multiple designs in this manual, are less susceptible to deterioration, it is important to note the implications of their eventual deterioration. When plastics breakdown, there is always a chance that microplastics can be leached into the water supply following degradation (Aaron Sakulich, WPI engineering professor, personal communication, November 18, 2019). This being said, most materials today, including clothing, tea bags, and take out cups, also leach microplastics into the water supply when washed, used, or disposed of. Therefore, wood-plastic composites are still considered by our team of collaborators to be a feasible option for use in sidewalk construction.

Cost Analysis of Sidewalk Materials

Design for a 3 Meter Sidewalk Stretch	Cost Estimate (in Colones)
Sidewalk with drainage holes over culvert Materials: Concrete Mix, Stone, Sand, Rebar, Culvert	**158472**
Sidewalk with drainage and side slit over culvert Materials: Concrete Mix, Stone, Sand, Rebar, Culvert	**158472**
Real wood with drainage grate over culvert Materials: Wood, Culvert, Stone	**83800**
Real wood with drainage grate Materials: Wood	**22500**
Gravel Mesh and Wood siding with drainage grates Materials: Wood, Gravel, Culvert	**81800**
Stone Pavers Material: Stone (Pavers)	**66375**
Concrete sidewalk with no culvert Materials: Concrete Mix, Stone, Sand, Rebar	**114672**

Cost Breakdown:

18” Circular Culvert 1m long: **14600**
Cement Mix (40 kilos): **4212**
Stone/ Piedra Quinta (1 metric ton): **17500**
Sand (1 metric ton): **17500**
Rebar (5”x5”): **19400**
Wood (1x4”) 83cm long: **750**
Stone (Pavers)(8x20cm): **295**

Drainage

Since there is not comprehensive drainage network in the Monteverde Municipality, it is very difficult to design drainage in the context of this Manual. This being said, it is suggested that landowners do their best to design drainage as water flows naturally. For example, if a sidewalk is being designed on a steep incline, with no rivers or other natural bodies of water nearby, it makes sense to just continue water drainage downhill towards the neighboring property. This makes a comprehensive network of sidewalks very important, as water directed from uphill could end up in a neighbor's yard or driveway if they have not yet constructed a sidewalk with appropriate drainage. It is expected that individuals who live adjacent to natural waterways such as rivers, lakes, and ponds, will direct the water from the sidewalk drainage ways previous into said bodies of water. This can be done through the use of a network of PVC pipes, creation of drainage passageways from the sidewalk to the nearest body of water, or designing a sidewalk close enough to a body of water to allow for direct drainage into it. Overall, collaboration with neighbors in building and designing sidewalks is highly encouraged in order to produce a sidewalk network that makes sense, and overcomes challenges relating to drainage.

If drainage ditches have not yet been installed but are deemed necessary to have between the sidewalk and roadway, they should be installed to the specifications exhibited in Figure 33.

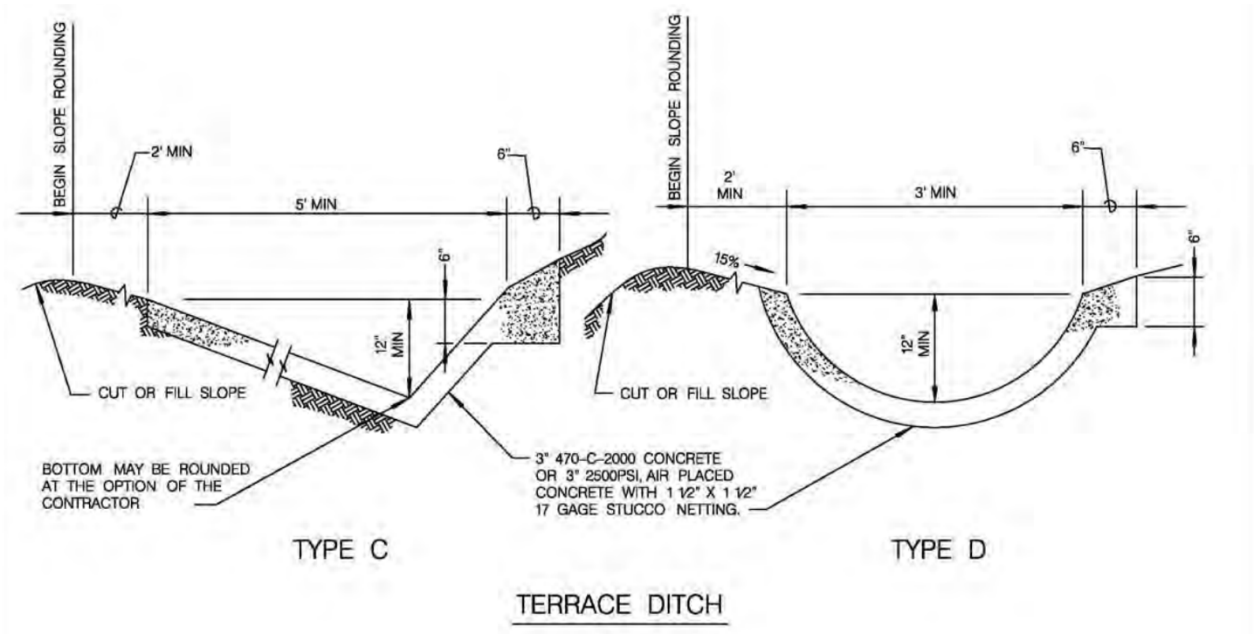


Figure 33 : Ways drainage ditches can be installed adjacent to sidewalks (City of San Diego…, 2016).

Railings

As stated in the Rules and Regulations section in this manual, it is necessary to install railings on either side of a sidewalk when the drop off from the side is over 70 centimeters, the slope of the sidewalk is over 20%, or there is a 15% slope on one side of the sidewalk. These sidewalks must be 90 centimeters in height above the sidewalk when used as a handrail, and 110 centimeters above the sidewalk to protect pedestrians from falling. In addition to this, the bars on the railing must be going vertically or diagonally to prevent injury, or must include a fence. Some examples of sufficient and insufficient railings can be found below.

Both railings pictured above have horizontal bars, which children can climb up and easily fall over. In addition to this, there are no real spots to hold onto it.

The first railing pictured here has diagonal bars, which prevents children from climbing up them. The second railing has wire mesh, which also makes it impossible to climb. They both have designated areas to hold them while walking.

Citations

Bandon, A. (2007, July 26). How to Lay a Budget-Friendly Gravel Path. Retrieved from https://www.thisoldhouse.com/sidewalks/21016412/how-to-lay-a-budget-friendly-gravel-path

Bani-Hani, K. A., & Senouci, A. (2015). Using Waste Tire Crumb Rubber As an Alternative Aggregate for Concrete Pedestrian Blocks. Jordan Journal of Civil Engineering, 9(3), 400–409. doi: 10.14525/jjce.9.3.3080

Better Homes & Gardens. (n.d.). How to Build Forms for a Patio or Walkway. Retrieved from https://www.bhg.com/home-improvement/kitchen/installation-how-to/how-to-build-patio-forms/

Chandratilake, R. & Kuruppu, G. (2012, June 28). Use of Recycle Glass as a Coarse Aggregate in Concrete. Retrieved from https://www.irbnet.de/daten/iconda/CIB_DC25129.pdf

City of San Diego Standard Drawings for Public Works Construction. (2016). Standard Drawings, 52.

Construction. (n.d.). Retrieved from https://action-materials.com/category/construction

CORCLIMA. (2019). About Us. Retrieved from http://corclima.org/en/

DIY Network. (2015, April 21). How to Pour a Concrete Walkway. Retrieved from https://www.diynetwork.com/how-to/outdoors/structures/how-to-pour-a-concrete-walkway

Fondo Para Guanacaste Community Fund. (n.d.). Special Funds. Retrieved from https://guanacastefund.org/welcome/

Gunasekaran, K., Annadurai, R., & Kumar, P. (2012). Long term study on compressive and bond strength of coconut shell aggregate concrete. Construction and Building Materials, 28(1), 208–215. doi: 10.1016/j.conbuildmat.2011.08.072

Hotel Belmar. (2016a). Home. Retrieved from http://www.hotelbelmar.net/

Hotel Belmar. (2016b). Our Unique Hotel. Retrieved from http://www.hotelbelmar.net/

Hotel Belmar. (2016c). Sustainable Tourism. Retrieved from http://www.hotelbelmar.net/

Nassar, R.-U.-D., & Soroushian, P. (2012). Strength and durability of recycled aggregate concrete containing milled glass as partial replacement for cement. Construction and Building Materials, 29, 368–377. doi: 10.1016/j.conbuildmat.2011.10.061

Polytek Development Corp. (n.d.). Concrete Mold Making - Starter Kit. Retrieved from

https://www.polytek.com/application/concrete-mold-making-starter-kit

Recycled Glass Concrete Terrazzo Tiles. (n.d.). Retrieved from https://www.chinaartificialstone.com/recycled-glass-concrete-terrazzo-tiles_p125.html

Shafigh, P., Mahmud, H. B., Jumaat, M. Z., & Zargar, M. (2014). Agricultural wastes as aggregate in concrete mixtures – A review. Construction and Building Materials, 53, 110–117. doi: 10.1016/j.conbuildmat.2013.11.074

Sonawane, Y. N., & Chitte, C. J. (2016). Waste Coconut Shell as a Partial Replacement of Coarse Aggregate in Concrete Mix - An Experimental Study. International Journal of Science and Research (IJSR), 5(4), 649–651. doi: 10.21275/v5i4.nov162608

Standard Details. (2019, December 25). Retrieved from https://www.clark.wa.gov/public-works/standard-details

Stanley, K. (2007, February 2). Officials Focus on Shoddy Sidewalks. The Tico Times Costa Rica. Retrieved from https://ticotimes.net/2007/02/02/officials-focus-on-shoddy-sidewalks

Stewart, S. (2017, February 4). Portland Landscaping & Permeable Paving - Landscape East & West. Retrieved from https://www.landscapeeast.com/blog/permeable-paving-portland-landscaping-2015-07

Suryakanta. (2014, April 7). WHAT IS BLEEDING IN CONCRETE AND HOW IT AFFECTS CONCRETE? Retrieved from https://civilblog.org/2014/04/07/what-is-bleeding-in-concrete-and-how-it-affects-concrete/

The Family Handyman. (2019, June 27). Form and Pour a Concrete Slab. Retrieved from https://www.familyhandyman.com/masonry/pouring-concrete/concrete-forms-and-pour-a-concrete-slab/

Western Interlock Inc. (2016, August 23). 64 Paving Install. Retrieved from https://westerninterlock.com/installation_guide/paving-stone-installation/64-paving-install/

Willow Creek. (n.d.). Paver Installation. Retrieved from https://www.willowcreekpavingstones.com/resources/installation-steps

World Health Organization. (2016). Road Safety: Number of road traffic deaths and distribution by type of road user, 2013. Retrieved from

2019 Riveted Grating - Royce Bar Grating. (2019). Retrieved from http://www.casaanita.es/