Estimation Tool for Residential Corrosive Drywall

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Corrosive drywall is a gypsum-based plasterboard that was manufactured in China and contains elemental sulfur and strontium. The drywall emits reduced sulfur gases in the chemical forms of hydrogen sulfide, carbonyl sulfide and carbon disulfide. These three gasses have been linked to the corrosion of metal components in homes including electrical wiring, refrigeration coils and fire safety devices creating a number of life safety issues. The import of Chinese drywall into the U.S. has been occurring since 1999. Estimates place the number of affected homes up to 38,000 and nearly two-thirds of those may be in the state of Florida. Several remediation protocols, including an interim protocol issued by the federal government, include the removal of all corrosive drywall from the home. This difficult and costly procedure will have a wide range of emotional, economic and environmental impacts. This paper presents the issues with corrosive drywall and provides Floridians an estimating tool to help gauge the financial burden of undertaking the interim federal remediation strategy.

Key Words: Drywall, Corrosive, Safety, Health, Financial Feasibility

Introduction

The full impact of the corrosive drywall problem in the U.S. is still emerging. As of May 7, 2010, the U.S. Consumer Product Safety Commission has received 3,082 reports from 37 different states, as well as the District of Columbia, Puerto Rico and American Samoa alleging that drywall manufactured in China is threatening health, corroding certain metal components in the home, or both (U.S. Consumer Product Safety Commission, 2010). These figures do not include cases that are reported at the state or local levels. Some estimates put the number of affected homes at 60,000 (Schmidt, 2009). Regardless of the final count, there is a significant emotional, economic and environmental impact involved in identifying and ultimately remediating the homes that contain corrosive drywall. Figure 1 illustrates that the quantity of imported Chinese drywall spiked in 2006 at nearly 218,100 metric tons (Crangle, 2009).

As of this writing, there is no single standard that has emerged for either the identification or remediation of homes affected by corrosive drywall. Yet, at least one company has been remediating homes since 2006 (Brinkman, 2009) and the federal government only recently released interim reports to provide guidance to homeowners for identifying and removing corrosive drywall (Tedder and McGuire 2009; U.S. Consumer Product and Safety Commission 2010b). One similarity between the remediation protocols offered by the private and public sectors is the recommendation to remove all of the source contaminant - the drywall - which contains traces of elemental sulfur (S) and elemental strontium (Sr). With a lack of inexpensive identification systems in place, this usually results in the replacement of all drywall in a home where at least a small amount of corrosive drywall exists.

This paper will also discuss the development of a remediation estimating tool. It will provide information about the development platform, the program flow and the core program logic. It will cover the inputs required from the user and discuss the testing procedures used to validate the tool's functionality. Lastly, this paper will draw conclusions about the estimating tool and suggest future enhancements.
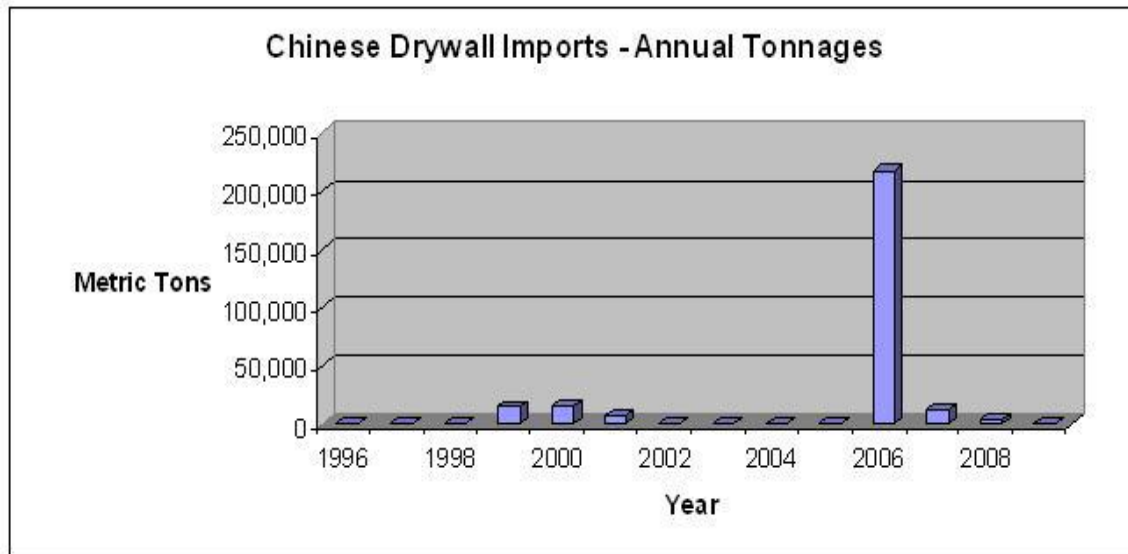
Figure 1. Total metric tons of imported Chinese drywall by year

Gypsum Board

Gypsum board, or as it is often referred to "drywall" or "sheetrock" is a ubiquitous building product that is often called wallboard, plasterboard or rock lathe. Drywall is most commonly used as a finishing cover over the structural members of walls and ceilings. Its widespread use is credited to the lower cost and shorter installation time needed to install and finish gypsum board over its predecessor, plaster (Armstrong et al. 2002). Unlike plaster, gypsum board is never wet during installation. Consequently, "drywall" became the popular name for the product.

Corrosive drywall, also known as Chinese drywall or imported drywall, is a gypsum-based drywall that contains chemicals not normally found in domestically produced drywall, most commonly strontium (Sr) and sulfur (S) (Singhvi 2009). Corrosive drywall off-gasses hydrogen sulfide (H2S), carbonyl sulfide (COS) and carbon disulfide (CS2) in a process that is accelerated by high humidity and heat (Gauthier, 2009). This off-gassing produces odors similar to rotten eggs, corrodes copper and other metals and may have detrimental effects on human health (U.S. Consumer Product Safety Commission, 2009a). The metal corrosion most commonly occurs in electrical switches and appliances with copper components such as refrigerators and televisions. Depending on the construction materials in the home, it may also affect piping for plumbing, gas lines and even fire suppression systems. The corrosion creates a risk for electrical fire, gas explosions, and may create an environmental hazard if certain refrigerants are released by damaged coils. It may also lead to the damage of smoke and carbon monoxide sensors, a hazard to life safety.

Scope of the Problem

As of May, 2010, the CPSC has received reports from 37 states and the District of Columbia (U.S. Consumer Product Safety Commission, 2010a). The largest number of complaints filed has come from the State of Florida (59%) followed by Louisiana (20%).

The federal response to the corrosive drywall problem is being managed by the Federal Interagency Task Force (Task Force) led by the Consumer Product Safety Commission (CPSC). The CPSC is working with the Environmental Protection Agency (EPA), Agency for Toxic Substances and Disease Registry (ATSDR) and the U.S. Department of Housing and Urban Development (HUD). The CPSC is also working with numerous state and local agencies such as the Florida Department of Health.

The Federal Interagency Task Force states that it does not believe there is a definitive test to determine whether a home has problem drywall. However, the Task Force does suggest contacting the builder about the materials used in

construction. It also provides some sentinel indicators that are indicative of the problem drywall. These include the smell of rotten eggs, corrosion of metal components such as copper coils and possible health problems. It also states that the "Made in China" labeling and a grayish colored gypsum core may be indicative of a problem. Recent cour rulings in Louisiana determined that drywall is a defective material problem not typically covered by home insurers.

Remediation

Remediation is the process of removing corrosive or damaged components from a home and then replacing the components with new drywall. Consequently, it is a two-step process employing a phase of demolition as well as a phase of reconstruction. Currently, a variety of remediation approaches exist that offer a broad range of cost, effort and sophistication for repairing homes afflicted with corrosive drywall. This variety exists because no single remediation protocol has been adopted by the private and public sectors.

On April 2, 2010, the Federal Interagency Task Force released the report Interim Remediation Guidance for Homes with Corrosion from Problem Drywall. This interim report is the first protocol by the federal government which outlines the four areas of the home to perform remediation efforts. The areas include the problem drywall as well as the systems that drywall-induced corrosion may have caused a safety concern for the inhabitants. The four areas with safety concerns include all fire alarm safety devices (including smoke alarms and carbon monoxide alarms), all electrical components and wiring (including outlets, switches and circuit breakers), and all gas service piping and fire suppression sprinkler systems.

The federal approach further states that in most cases all drywall should be removed from the home until the practical and scientific challenges of identifying the specific corrosive sheets can be overcome. If these challenges are met, and no other corroborating evidence of corrosion exists, it is an option to leave the drywall in place. The government also acknowledges that further research may add or subtract from the components that need replacement. In the future, this may eliminate copper wiring with an insulated shield but could add copper piping for water lines. The government does not have sufficient evidence to show that cross-contamination between components currently exists or that high efficiency particulate air (HEPA) vacuuming is required. However, it encourages all property owners to consider the remediation approaches used by other professionals before committing to a single course of action. The resulting removed drywall taken to the landfill is not currently considered a toxic waste in the state of Florida due to the low amount of corrosive elements.

Methodology

For many Florida homeowners, calculating the cost of a remediation that satisfies the federal interim protocol is a difficult task. The protocol covers many areas in the home and accurate construction cost information is not readily available. If the estimate is not self-performed, one means for obtaining a cost estimate would be to ask a professional contractor. Even then it is difficult to gauge the accuracy of an estimate without comparing it to a second or third estimate which takes additional time and effort. As such, a remediation estimating tool ("Estimating Tool") was developed to provide Floridians with the means to generate a rough conceptual estimate of construction costs for a remediation. The Estimating Tool is a software program that provides a remediation estimate based on specific house details provided by the user and cost information provided by the R.S. Means publication 2009 Square Foot Costs..

Platform

The Estimating Tool was developed using Microsoft Office Access ("Access"). Access is a pseudo relational database management system from Microsoft that combines the relational Microsoft Jet Database Engine with a graphical user interface and software development tools. The choice to use Access as the development platform is made for three reasons. First, the final program is a stand-alone application that can be emailed to any interested parties. Second, the look-and-feel of the program is similar to other Microsoft programs which many computer users are already familiar with. Third, the program is robust enough to allow other programmers to add, change or remove functionality. All source code, written in Visual Basic for Applications (VBA), will remain accessible through the Access interface.

User Inputs

This Estimating Tool will require the user to perform a number of quantity take-offs, measurements and observations of the house being estimated. Since the application uses a database to store the information, the user can perform the required steps while using the program in a limitless number of sittings. All information stored in the program is saved until the user chooses to delete it.

The first responsibility of the user is to provide a rough estimate of the total square footage of finished space in the home. This number should exclude unfinished areas often found in garages, storage spaces, attics and unfinished basements. Next, the user must create an inventory of each room in the house and record specific features about that room. Only rooms containing drywall should be included in the inventory. The features of the room required by the program include the room's overall dimensions in terms of length, width and ceiling height. Also, the number of smoke alarms and carbon monoxide detectors should be recorded as well as their type and manufacturer. Information on the thickness of the ceiling drywall, attic insulation and the type of finish of the ceiling should also be noted.

After the room information is entered into the Estimating Tool, information about the walls within each room is required by the program. All walls covered with drywall, including interior partition walls, should be included in this step. The length and height of the wall are needed, as well as whether the wall has drywall on one or two sides. Other observations to be noted are the thickness of the drywall used on the wall, the type of finish and the type of insulation (if applicable). The last step required of the user is to record information about the openings found in each wall. Openings most commonly include doors and windows. The total square footage of drywall calculated for the home will exclude the total square footage of the openings.

Square Foot Costs

The database back-end of the Estimating Tool was designed to capture two major groups of information. The first group includes the specific dimensions and materials of the house. These are collected by the program user and entered into the database through the graphical user interface (GUI). The second group of information includes the actual square foot costs related to the various stages and components of the remediation. These include square foot costs for replacing drywall, insulation, electrical systems and others. The first release of the Estimating Tool will include at lease one square foot estimate for each category and stage of remediation based on information provided by R.S. Means in their publication 2009 Square Foot Costs. The data provided in the first release is based on information from the year 2009. As construction costs change with time, it will be necessary to update these values. Additionally, the specific house being entered into the program may contain elements not pre-populated in the first program release. Under these circumstances, the user will have the capability to update and add additional values to the square foot construction costs through the GUI.

Program Flow

Figure 2 visually demonstrates the program flow of the Estimating Tool. Once a user opens the program on his or her computer, a window will appear. This is the main navigation window in the program that will allow the user to perform one of two functions. The first function is to go to the estimating window where the user will be able to create a new estimate, edit an existing estimate, delete an old estimate or run the estimate report. The second function is to perform maintenance on the construction costs in the database. The maintenance functionality allows the program to be updated as building costs change over time or the user wishes to add additional costs. The user can edit or delete the construction costs that have been pre-populated into the program or add additional ones if needed for their specific homes. By providing this option, it is not necessary to hard-code any variables into the source code of the program. There will be a total of nine windows used in the maintenance of the cost data in the program.
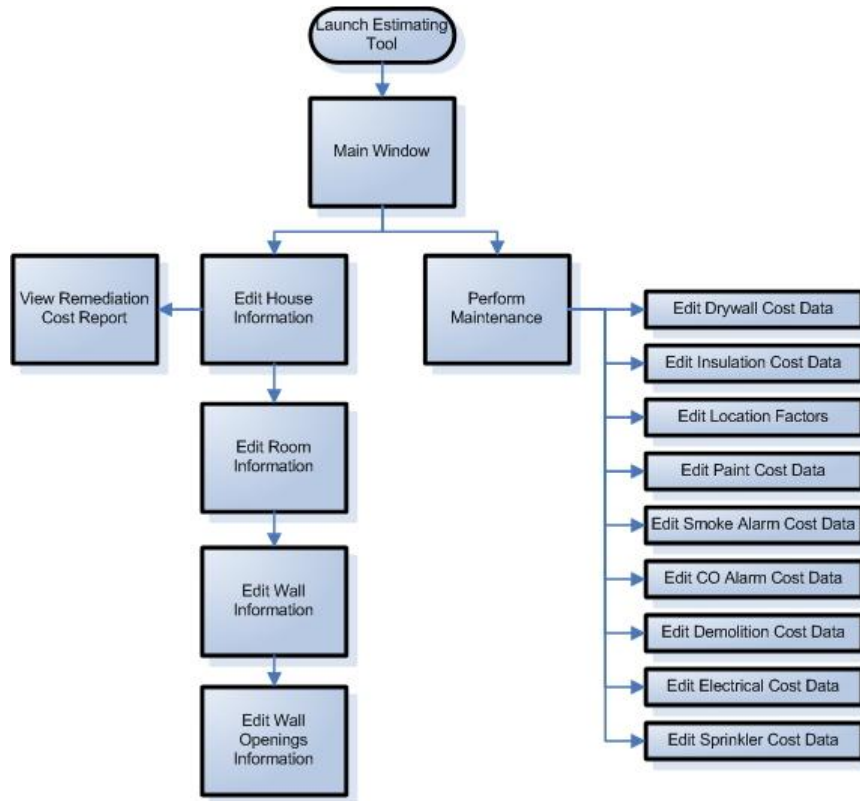
Figure 2. Program flow of the Estimating Tool

Main Program Logic

The core programming logic for the Estimating Tool is executed every time the user chooses to view the Remediation Cost Report. Before any information is displayed to the user, the program will run through the linear steps and logical loops that are shown in Figures 2 through 4. The first step of this logic is to query the database for specific information about the house being estimated including the total square footage of finished space. The total square footage of finished space will allow the program to create remediation estimates for the costs of demolition, electrical work and sprinkler replacement (if applicable).

After the first three estimates are calculated, the program will enter its first logical loop, looping through every room in the house. The room data will provide costs for smoke detectors, carbon monoxide detectors, ceiling insulation, ceiling paint and ceiling drywall. In each first level loop, the program will begin the second level loop illustrated in Figure 4.

The second level loop is responsible for gathering information on the walls entered for each room. The first step in this loop is to collect the total area of any openings in the walls. These openings are subtracted out of the total drywall in the home and are collected in a third level loop. Until the program encounters the last opening entered by the user, the core logic will keep adding together the openings to get a total area of these openings. Next, costs associated with insulation, paint and drywall are added to the total costs of these three building components collected for the house. This process is then repeated for each wall in the room. When the program fails to encounter any more walls, the logical loop is exited and the processing returns to the first level loop.

After all the rooms, walls and openings have been processed, the information gathered and calculated by the program is displayed to the user through the Remediation Cost Report. The Remediation Cost Report is the final output of the program. The report is designed to be printed for future reference by the program user. It will contain

basic project information (such as project name and location), square foot calculations and final remediation costs for each component being evaluated by the program.
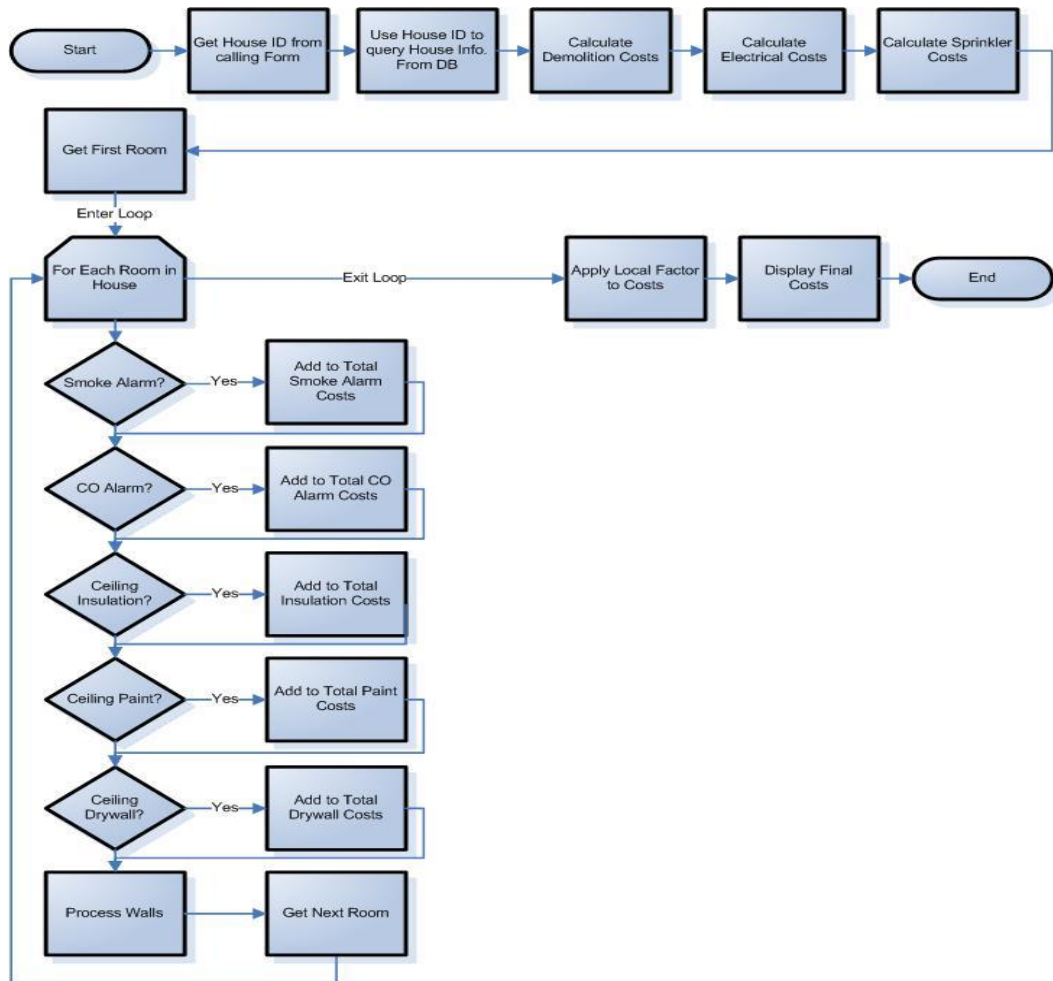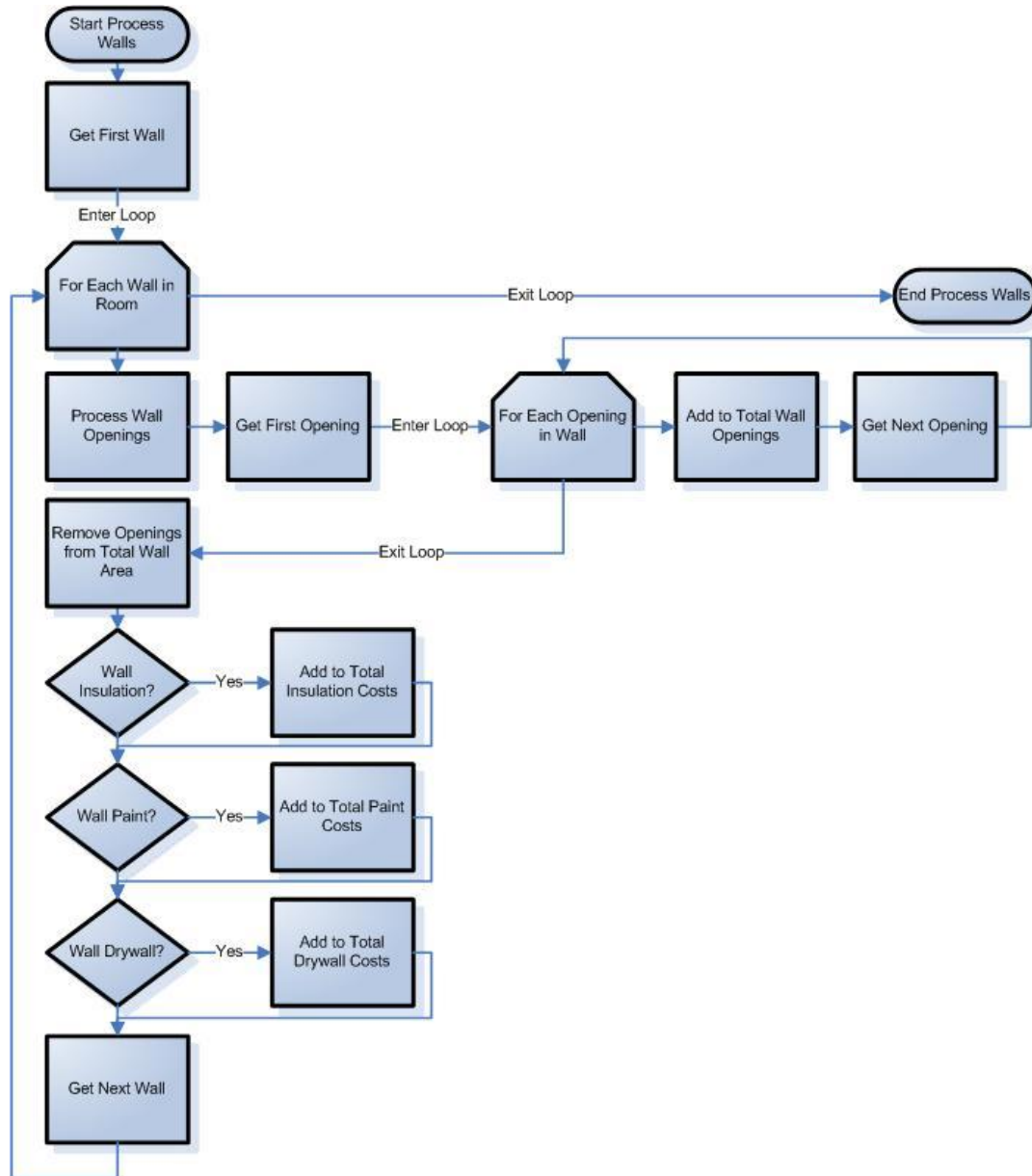

Figure 3. Core logic of the Estimating Tool

Figure 4. Second and third level loops of the core programming logic for the Estimating

Results

In order to properly test the Estimating Tool, it was necessary to design a test house that contains all the elements that are included in the functionality of the program. The test house consists of two rooms and all interior walls and the ceiling are assumed to be covered in drywall. A total of three doors and two windows are included in the test house. The doors and windows serve as "openings" that can be subtracted out of the total drywall calculations. In addition, a small partition wall is included in the north room. The partition is needed to test the double-counting feature of the Estimating Tool. The double-counting feature is used when a wall has drywall on two sides. Under these circumstances, the square footage of drywall on that wall is counted twice by the program.

The overall dimensions of the rooms are shown in Figure 5, the building floor plan. The wall with the two windows is on the north side of the building and the entrance is found on the south side. All three doors are 3 feet wide and

both windows are 4 feet wide. The interior dimensions of both rooms are 10 feet long by 20 feet wide. The interior partition that splits the north room is 5 feet in length. The south room is named Room 1 and the north room is named Room 2. For the model, all doors are 7 feet in height, windows are 2 feet in height and the building walls are 8 feet in height.
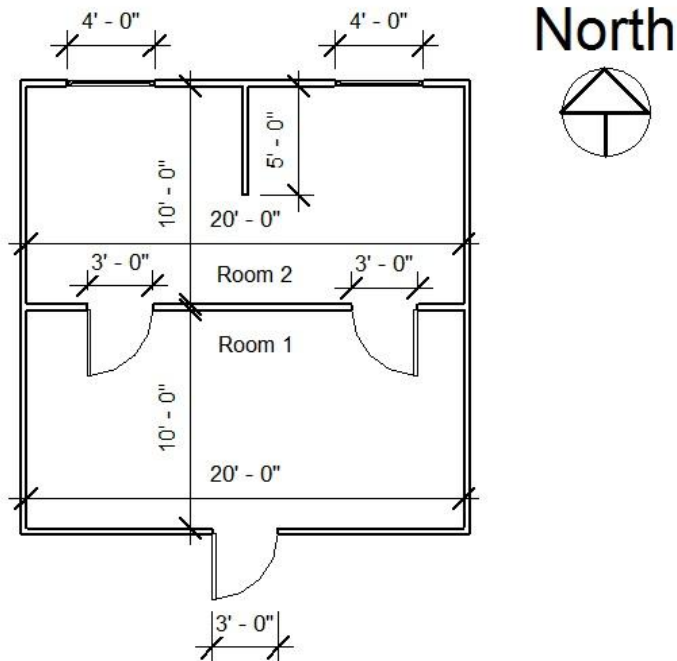

Figure 5. Floor plan of the house used to test the Estimating Tool

In addition to assigning physical dimensions to the test house, it was also necessary to make assumptions about the materials and systems included in its construction. The following material selections and assumptions were made for the test house:

- The test house has a total of 400 square feet of finished space

- Demolition costs – does not include disposal ($6.00 / sf)

- Electrical work costs ($16.50 / sf)

- The test house has a wet pipe sprinkler system ($4.78 / sf)

- The drywall used on the walls is a standard drywall, 1/2" in thickness ($1.39 / sf)

- The drywall used on the ceilings is a standard drywall, 5/8" in thickness ($1.41 / sf)

- All exterior walls are insulated with a fiberglass insulation at 3 1/2" of thickness ($1.00 / sf)

- All ceiling spaces are insulated with a fiberglass insulation at 6" of thickness ($1.22 / sf)

- None of the interior walls are insulated

- All drywall on the walls has been painted with a primer and two coats of paint ($1.03 / sf)

- All drywall on the ceiling has been painted with a primer and only one coat of paint ($0.76 / sf)

- Each room has 1 First Alert SA302CN Smoke Detector ($23.00 / unit)

- Each room has 1 Kidde / Lifesaver 9C05 CO Detector ($48.00 / unit)

- The closest location factor to the test house is Jacksonville, FL (.8)

Expected Results

There are a total of 16 fields on the Remediation Estimate window whose values result from the information entered and selected by the user, cost data provided by the R. S. Means publication 2009 Building Construction Cost Data, and calculation logic provided by the program. In order to validate that the Estimating Tool performs as designed, it was necessary to manually calculate expected values for each of the 16 fields before running the program on the test house. It will then be possible to compare the manual calculations to the actual output of the program. The manually calculated value for each of the 16 fields follows.

Field: Gross Wall Area (sf). Gross wall area is the total area of all the walls in the house without subtracting out any openings such as the doors or windows. The expected gross wall area of the test house is 1,040 square feet. This total is the summation of the individual areas of each of the 10 walls.

Field: Gross Openings (sf). The "gross openings" of a house is the total area of all the wall openings entered by the program user. In the test house, this includes three doors and two windows. The "gross openings" is 79 square feet.

Field: Net Wall Area (sf). The net wall area is simply the subtraction of Gross Openings from Gross Wall Area, or 1,040 square feet less 79 square feet which equals 961 square feet for the test house.

Field: Ceiling Area (sf). Ceiling area is the total area of all the ceilings in the house which are entered per room. In the test house, there are a total of two rooms which generate a total ceiling area of 400 square feet.

Field: Total Drywall (sf). Total drywall is the summation of Net Wall Area and Ceiling Area. For the test house, the sum of 400 square feet and 961 square feet is 1,361 square feet.

Field: Electrical Estimate ($). The electrical estimate is generated by multiplying the total square footage of finished space by the cost of electrical work per square foot. In the test house, the assumption is made the cost of installing new electrical work is $16.50 per square foot. The total cost of a new electrical system in the test house costs $6,600.

Field: Demolition Estimate ($). The demolition estimate is generated by multiplying the total square footage of finished space by the cost of demolition work per square foot. In the test house, the assumption is made the cost of demolition is $6.00 per square foot. The total cost of the demolition in the test house costs $2,400.

Field: Sprinkler Estimate ($). The sprinkler estimate is generated by multiplying the total square footage of finished space by the cost of installing a sprinkler system per square foot. In the test house, the assumption is made the cost of the sprinkler system is $4.78 per square foot. The total cost of the sprinkler in the test house costs $1,912.

Field: Drywall Estimate ($). The drywall estimate is generated by multiplying the square footage of a particular type of drywall by the cost for that particular type as selected by the user. Then, all the individual costs are added together to create a grand total which is displayed in the Drywall Estimate field. In the test house, there are two different types of drywall used. The drywall used on the walls is a half inch in size ($1.39 per square foot) and the

drywall on the ceilings is made from a heavier 5/8" type ($1.41 per square foot). Shows the resulting grand total for the two types costs $1,898.

Field: Insulation Estimate ($). The insulation estimate is generated by multiplying the square footage of a particular type of insulation by the cost for that particular type. Then, all the individual costs are added together to create a grand total that is displayed in the Insulation Estimate field. In the test house, there are two different types of insulation used. The exterior walls use 3 1/2" insulation ($1.00 per square foot) and the ceiling has 6" insulation ($1.22 per square foot). There is no insulation in the interior walls. Shows the resulting grand total for insulation costs $1,091.

Field: Paint Estimate ($). The paint estimate is generated by multiplying the square footage of a particular type of paint by the cost for that particular type. Then, all the individual costs are added together to create a grand total displayed in the Paint Estimate field. In the test house, there are two different types of paint used. The walls are painted with a primer and two coats of paint ($0.76 per square foot). The ceilings are painted with a primer and only one coat of paint ($1.03 per square foot). Shows the resulting grand total for the two types costs $1,292.

Field: Smoke Alarms ($). The cost of the smoke alarms is calculated by multiplying the total number of smoke alarms by the cost associated with each type. The test house has a total of two smoke alarms, one per room. Both alarms cost $23 each. The total cost of smoke alarms is $46.

Field: CO Alarms ($). The cost of the carbon monoxide (CO) alarms is calculated by multiplying the total number of CO alarms by the cost associated with each type. The test house has a total of two CO alarms, one per room. Both alarms cost $48 each. The total cost of CO Alarms is $96.

Field: Subtotal (National Avg.) ($). The subtotal value is the summation of all the previous 8 cost estimates. Because the cost data provided by R.S. Means has not been adjusted to a specific Florida locality in this field, it is a national average value. The individual costs sum is $15,339.

Field: Total (Location Adjusted) ($). The location adjusted total is the product of multiplying the national average costs found in the Subtotal field by the location factor selected by the user. In this case, the test house was given a location factor of Jacksonville, FL which has a value of 0.8. Multiplying $15,339 by 0.8 creates a product of $12,271.

Field: Cost Per SF ($). The cost per square foot value results from dividing the location adjusted total displayed in the Total (Location Adjusted) field by the finished square footage of the house. For the test house, it is the resultant of dividing $12,271 by 400 square feet which results in a value of $30.68.

Actual Results

The test house was entered into the Estimating Tool per the specifications of the test procedure. All rooms, walls and openings were dimensioned per the floor plans and elevations. All systems and materials selected for the test house were inputted into the program identically to the test procedure. The program was then prompted to generate a Remediation Cost Report for the test house. Figure 6 shows the output provided by the Estimating Tool.

Comparison of Test House to the Average House

The domestic manufacturer of drywall, USG Corporation, manufactures 1/2" *Sheetrock* which weighs 1.6 pounds per square foot and 5/8" Sheetrock which weighs 2.2 pounds per square foot (USG, 2009). According to the Estimating Tool, the 400 square foot test house with a simple configuration of two rooms, three doors, two windows and a small partition wall has a total of 1,361 square feet of drywall. If the entire test house were made from these two Sheetrock products, the 961 square feet of walls would weigh 1,538 pounds. The ceiling would weigh 880 pounds. Summed together, the total weight of drywall in the test house would be 2,418 pounds. If the test house were increased in size by a factor of 5 to accommodate 2,000 square feet of finished space, the drywall would weigh approximately 12,090 pounds or 5.5 metric tons.

It has been estimated that a single 2,000 sf home contains 7.3 metric tons of drywall (Crangle, 2009) which is 33% more weight than the 2,000 square foot test house. This difference may be explained by the small number of partitions found in the test house. The test house contains only two interior partitions whereas an average home, which would contain multiple rooms, would have more interior partitions increasing the total square footage of drywall.

Figure 6. Remediation Estimate window of the Estimating Tool displaying the costs associated with the test house

Conclusions

The Estimating Tool has a number of limitations that can make its use cumbersome, maintenance intensive, possibly inaccurate and not fully accessible. However, each of these limitations can be addressed with enhancements to future versions of the program. These enhancements vary greatly in their level of technical sophistication, but all are feasible with the proper computer programming skill sets. Developing the first version of the Estimating Tool in Microsoft Office Access ("Access") was done specifically to allow programmers visibility to the program source code for additions, deletions and modifications to the program logic for future releases.

Notable limitations for the Estimating tool include:

- Large quantity of data entered

- Variation of material cost over time

- Changes in design during remediation

- Limits of standalone software package

In summary, the Estimating Tool has the potential to provide the users a simpler, more accessible and more accurate means for creating a remediation estimate of a home containing corrosive drywall. However, these future

enhancements will require additional time and skill to implement, and in all likelihood, will cost money. Until the changes are implemented, the first release of the Estimating Tool accurately provides users a ballpark estimate of a remediation effort based on the current inputs captured in the program.

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