PROJECT

DCC – STUDY FERMACELL PRODUCT
Réf. L2C02180511

9036 6170 Qc Inc.

A/s Sylvain COUTURE, Ing.

Structural expertise report on the use of Fermacell products in a multi-storied wooden construction project

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OBJET : *DCC – STUDY FERMACELL PRODUCT*

N/Dossier n° : L2C02180511

Dear,

Please find attached the expert report on the use of Fermacell products in a multi-storey wooden project. This study was conducted by Guillaume Gélinas, Eng. M.Eng, and Luc-Alexandre Faucher, Eng., M.Sc.A. under the supervision of Jean-Philippe Carrier, structural engineer and senior partner who also prepared and signed this expert report.

We hope that this report will meets all your expectation.

Best regards,

JP Carrier ing.

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Scope of the study

Mr. Sylvain Couture commissioned the firm L2C Experts to make a comparative study of the costs of building materials for a structure built with Fermacell product compared to a structure conventionally built with a 1½ " acoustic lightweight concrete topping cast on the floors of each floor of a light wood frame structure. The analyzed structure is a new four (4) story building located in Longueuil, Quebec. The floor structure is of light wood frame construction and consists of openwork wood beams on the 2nd, 3rd and 4th floors and wooden roof truss at the roof level. The whole thing rests on a reinforced concrete transfer slab that houses an underground parking lot composed of columns and walls of reinforced concrete foundations. The building is supported by a set of superficial foundations consisting of runners under the walls or isolated serifs under the columns.

Figure 1 – 3D view of the building

The study is interested in the savings of reinforcement steel and concrete for the foundations and the transfer slab of the ground floor. For this step, only the gravitational loads, i.e. dead, live and snow loads, were considered. It should be noted that the results obtained are quantitative, either in volume or weight of material. An estimate of the amount of savings is also made based on the reinforcement steel and concrete prices of the market as of May 29, 2018 in Longueuil, Quebec.

In a second step, the study focused on the savings of the seismic recovery system. The seismic analysis was limited to evaluating the nailing differential and the type of OSB on the shearing walls. The evaluation of the alteration of the anchors of the shearing walls has not been evaluated in this report.

The study focuses only on the impact of using the Fermacell product on certain building components, namely the foundations, the ground floor structural slab and the vertical load recovery system. The following elements are excluded from the comparative analysis:

Comparison of Fermacell product costs compared to 1½ " lightweight concrete topping

- Comparison of installation costs and the impact on the schedule of the Fermacell product compared to the 1½ " concrete topping (laying, finishing, curing, etc.)
- Comparison of impacts other than structural impacts (acoustic, architectural, etc.)
- Any other use than the studied case
- Etc.

The building was not chosen to benefit or disadvantage the Fermacell product. The analysis represents a concrete example where the Fermacell product could have been used to reduce the quantities of materials from the other structural elements on the project. The analysis is not a guarantee that savings can be replicated in all projects or situations. Much greater savings could be made if the reduction in building weight through the use of Fermacell dry screeds prevented the use of deep foundations such as piles or the use of a structural slab. One could even think of adding a floor since the reduction of the weight of the floors is cumulative. A six (6) storey building with Fermacell dry screeds is only 10% heavier than a five (5) storey building with light-weight concrete topping.

No. of floors	Weight of building with lightweight concrete screed (lb / ft²)	building with fermacell (lb / ft²)	Decrease in weight
6	477	432	10%
5	395	359	10%
4	313	286	9%
3	231	213	8%
2	149	140	6%
1	67	67	-

Figure 2 – Approximate weight of a light frame building

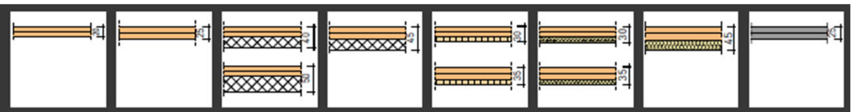
Product Description Fermacell and concrete topping

In this study, two construction methods are compared. The first method involves pouring a light concrete layer about 40mm (1 ½ ") on the wood-framed floors. Different membranes are used between the wooden decking and the concrete topping. The concrete is poured on the floors in the liquid state and will become solid after a period of cure or drying. Although it's hard to imagine, this topping is non-structural and its sound insulation properties remain the main reason for its use. Generally, a concrete of normal density, is approximately 2400 kg / m³ is used. The concrete topping therefore has a weight of 91 kg / m² or 0.9 kPa which equates to approximately 20 lb / ft². This practice is mostly used in residential or multi-residential buildings. When the floor joist manufacturers design the beams with the concrete topping poured on the floors, they add 20 lb / ft². Although less frequently used, there is also lightweight concrete with a density of 1800 kg / m³, or 75% of the weight of normal density concrete. The lightweight concrete topping will then have a weight of 15 lb / ft². In order to make a more conservative comparative study, lightweight concrete will be used in the various calculations.

The second method is to use a dry screed in the form of FERMACELL panels. The system is ready to install after the assembly of the structure.

Figure 3 – Laying Fermacell Dry Screeds

Several formats and types of FERMACELL floor plates are available and currently available on Type 2E31 and 2E32 plates. These two products are those that are easily used to replace poured concrete topping in place and have the same weight of 0.25 kPa or 5 lb / ft². Here is the table summarizing the physical properties of Fermacell dry screeds:



fermacell Flooring Element	2 E 11	2 E 22	2 E 13 (2 E 14)	2 E 23	2 E 31 (2 E 33)	2 E 32 (2 E 34)	2 E 35	Powerpanel H_2O Flooring Element
Construction	2 x 10 mm Gypsum Fibreboard	2 x 12,5 mm Gypsum Fibreboard	2 x 10 mm Gypsum Fibreboard + 20 mm (+ 30 mm) Polystyrene hard foam WLG 040	2 x 12,5 mm Gypsum Fibreboard + 20 mm Polystyrene hard foam WLG 040	2 x 10 mm (2 x 12,5 mm) Gypsum Fibreboard + 10 mm wood fibre WLG 050	2 x 10 mm (2 x 12,5 mm) Gypsum Fibreboard + 10 mm mineral wool	2 x 12,5 mm Gypsum Fibreboard + 20 mm mineral wool WLG 040	2 x 12,5 mm Powerpanel H_2O Flooring Element
Element thickness (mm)	20	25	40 (50)	45	30 (35)	30 (35)	45	25
Point load (kN/m²)	0,23	0,29	0,23 (0,24)	0,29	0,25 (0,31)	0,25 (0,30)	0,33	0,25
Thermal resistance (m² K/W)	0,06	0,08	0,56 (0,81)	0,58	0,26 (0,28)	0,28 (0,31)	0,31	0,14
Building material class according to DIN EN 13501 or * DIN 4102	$A2_{fl}$-s1	$A2_{fl}$-s1	B_{fl}-s1	B_{fl}-s1	B_{fl}-s1	$A2_{fl}$-s1	$A2_{fl}$-s1	A1*

Figure 4 – Physical Properties of Fermacell Dry Screeds

Description of the building

The building used for the comparative analysis is a four (4) storey wooden building with a concrete basement located in Longueuil. The structure of the building is made of beams, roof trusses and load-bearing walls of light timber framing. The 16,400 sq. Ft. (15 24 m²) wooden building rests on a concrete transfer slab. There are two deep slabs totaling 8125 ft² (755 m²). The building is based on shallow, isolated foundations on medium to very dense gray till. The seismic class of this soil is class D. Lateral forces are taken up by shearing wall nailed with OSB panels.

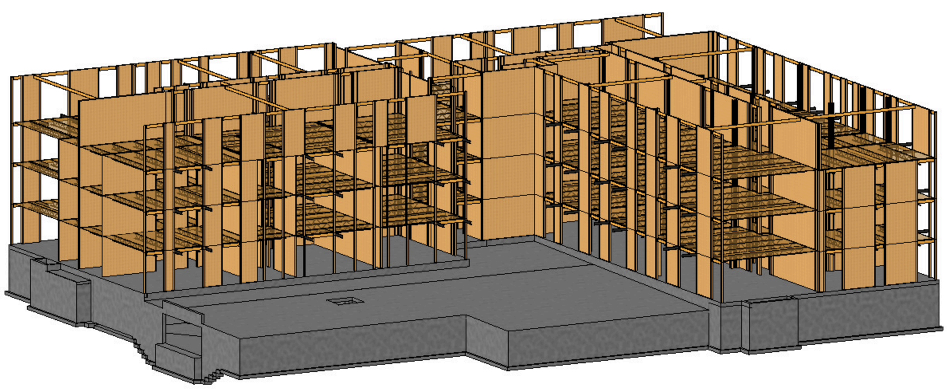


Figure 4 – Building Modeling on REVIT by L2C

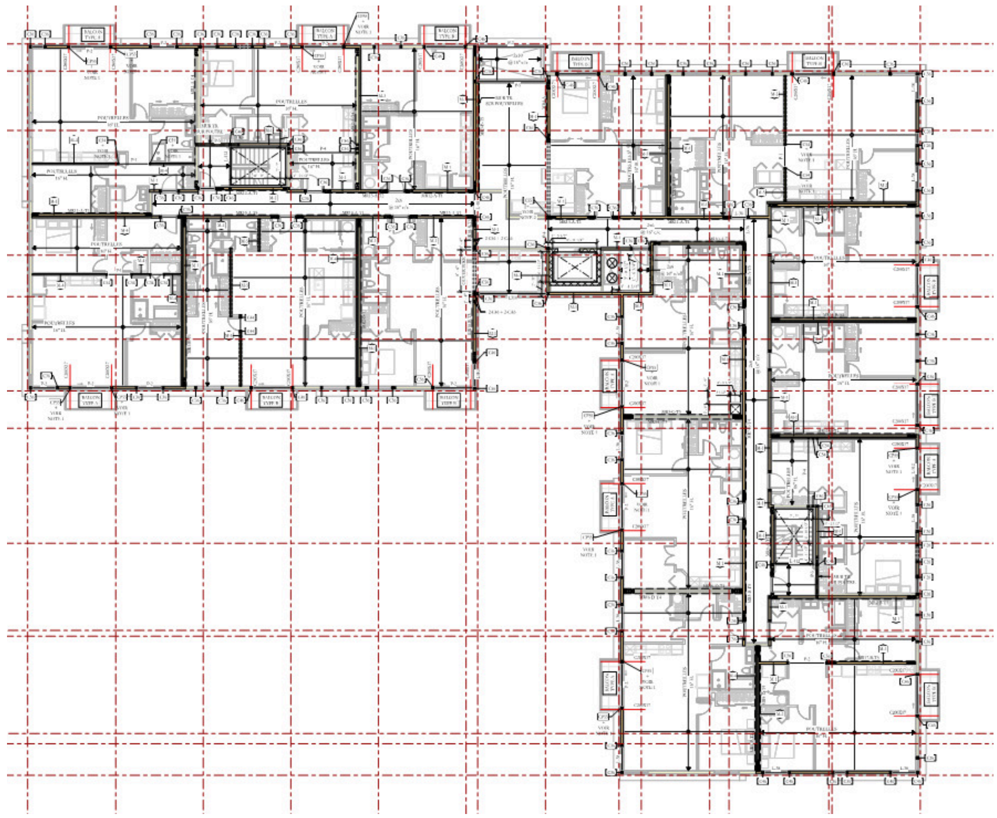


Figure 6 – Plan view of the building

Description of floor compositions

The four (4) story building analyzed is a wood frame building. The Fermacell product is installed in the floor composition instead of the 1½ " lightweight concrete topping in the following figure.

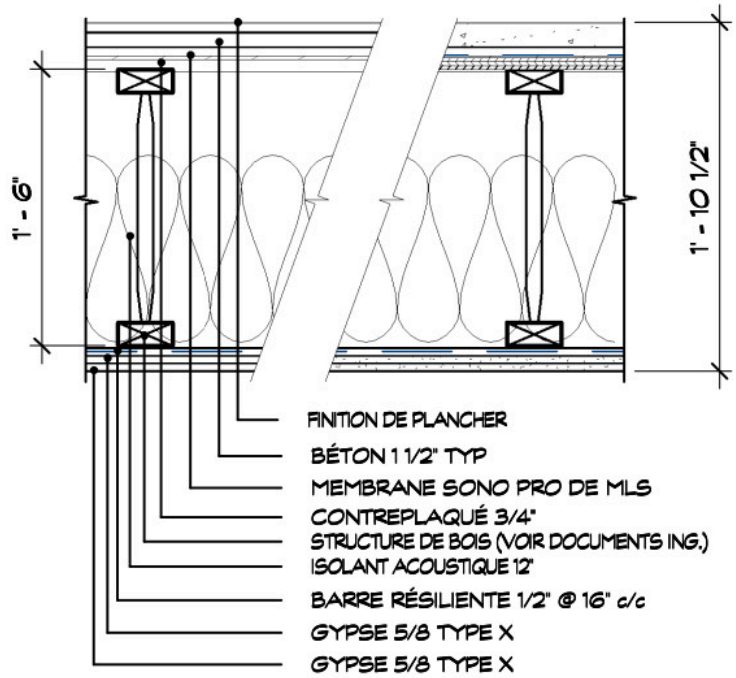


Figure 7 – Floor Composition of Case # 1

With a composition using a lightweight concrete topping, the dead load of the floor is 2.05 kPa (43 lb / ft²). Using the Fermacell product, the result is 1.57 kPa (33 lb / ft²). It is this reduction in weight on each floor that creates the savings of materials at the level of the foundations, the structural slab and the seismic recovery system. The following table shows the total weight of the structure according to the analyzed case. The reduction of the dead load and the total load for cases # 2 and # 3 are compared with reference to case # 1.

The three cases analyzed are the following:

1- Case # 1 - Structural slab on the ground floor of 12 " with a 1½ " lightweight concrete topping on the floors
2- Case # 2 - Structural slab on the ground floor of 12 " with Fermacell product on the floors
3- Case # 3 - Structural slab on the ground floor of 11 " with Fermacell product on the floors

	Case #1	Case #2	Case #3
Roof Dead Load (lb / ft²)	20	20	20
4F Dead Load (lb / ft²)	42	33	33
3F Dead Load (lb / ft²)	42	33	33
2nd F dead load (lb / ft²)	42	33	33
GF dead load (lb / ft²)	174	174	161
sub-total dead load (lb / ft²)	320	293	280
Reduction compared to case # 1 (%)	-	9,13%	13,11%
Live load and snow (kPa)	210	210	210

Total dead, live and snow loads (lb / ft²)	530	503	490
Reduction compared to case # 1 (%)	-	5,53%	7,93%

Figure 5 – Table of reduction of the loads according to the analyzed cases

Savings at the level of foundation elements

For the calculation of the foundations, a descent of the load was carried out for each case under study. Each column was assigned a foundation type (A to H) based on the loads it was to take back. The following tables show the dimensions and reinforcement of each type of foundation. A value of $130/m3 was used to calculate concrete costs. A price of $ 1,500 per ton of steel was used for the frame.

Isolate footing chart - 1½ " concrete floor		
Types	Dimensions	Reinforcement Steel
A	3'-6" x 3'-6" x 10" Thkns.	3-15M
B	5'-0" x 5'-0" x 12" Thkns.	6-15M
C	6'-0" x 6'-0" x 14" Thkns.	9-15M
D	6'-6" x 6'-6" x 16" Thkns.	10-15M
E	7'-0" x 7'-0" x 16" Thkns.	8-20M
F	7'-6" x 7'-6" x 18" Thkns.	9-20M
G	8'-0" x 8'-0" x 18" Thkns.	11-20M
H	8'-6" x 8'-6" x 20" Thkns.	12-20M

Figure 6 – Isolate footing Types - Case # 1 - Dimension, Reinforcement and Total Cost

Isolate footing - FERMACELL slab GF 12 "		
Types	Dimensions	Reinforcement Steel
A	3'-6" x 3'-6" x 10" Thkns.	3-15M
B	5'-0" x 5'-0" x 12" Thkns.	5-15M
C	6'-0" x 6'-0" x 14" Thkns.	8-15M
D	6'-6" x 6'-6" x 16" Thkns.	9-15M
E	7'-0" x 7'-0" x 16" Thkns.	8-20M
F	7'-6" x 7'-6" x 18" ÉP.	8-20M
G	8'-0" x 8'-0" x 18" ÉP.	10-20M
H	8'-0" x 8'-0" x 20" Thkns.	10-20M

Figure 7 – Isolate footing - Case # 3 - Dimension, Reinforcement and Approximate Total Cost

The reduction of the isolated footings material is approximately 5% for cases # 2 and # 3 compared to case # 1.

To see the location plan of footing, refer to the following figure. The blue footings are the footings under the deep slab. They are not affected by the reduction in charges brought by the use of the Fermacell product.

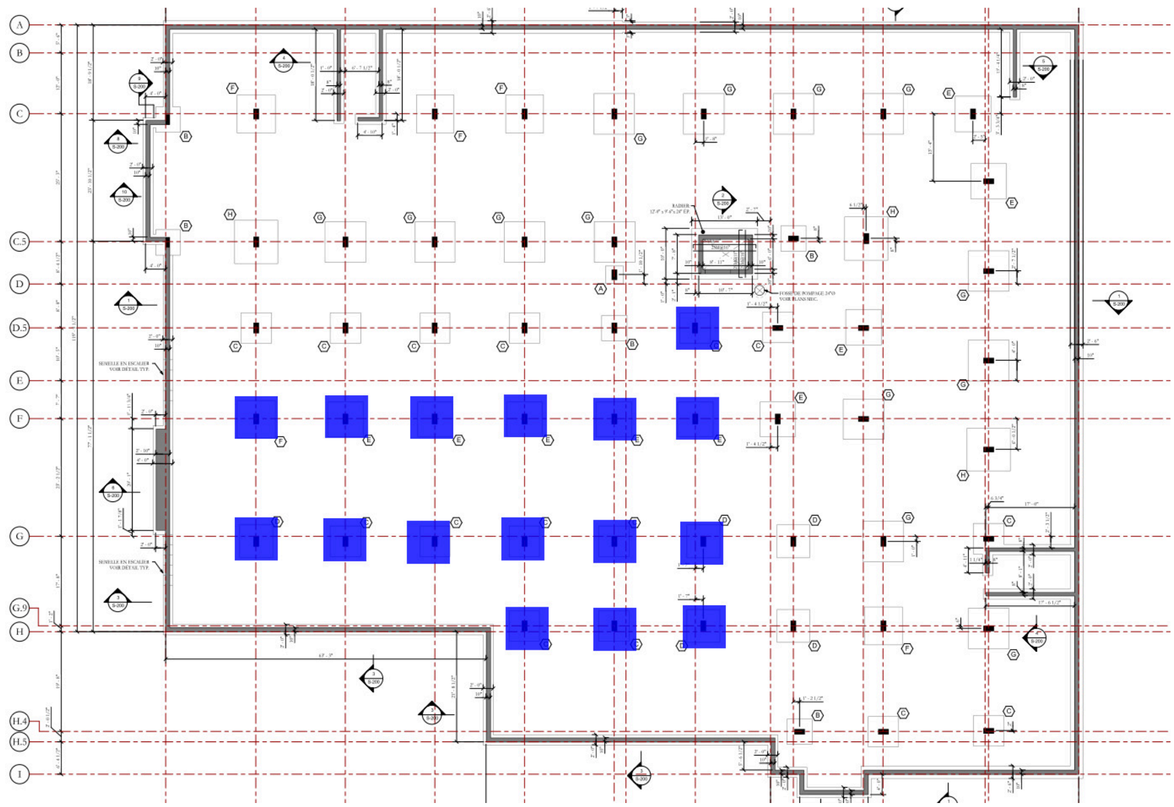


Figure 8 – Semelles Types - Cas #3 - Dimension, Armature et Coût total approximatif

Savings in structural slabs

First of all, the reduction of loads caused by the use of Fermacell product allowed the use of a structural slab having 11 " thick, 1" less than the slab with a lightweight concrete topping. However, reducing the thickness of concrete does not automatically mean that this option is more economical, since a reduction in the thickness of concrete consequently leads to an increase in reinforcing steel. It is for this reason that an analysis of the two thicknesses of slab has been made.

Three structural slab models were therefore modelled, that is, one model for each case under study. The SAFE software was used to generate the forces and to size the required rebars. The parameters to generate the rebars automatically are the same for all models and are defined in the

"Analysis Parameter" section. Only the amount of reinforcement of the ground floor slab has been calculated. Indeed, there is no saving of reinforcing steel and concrete on the deep slabs

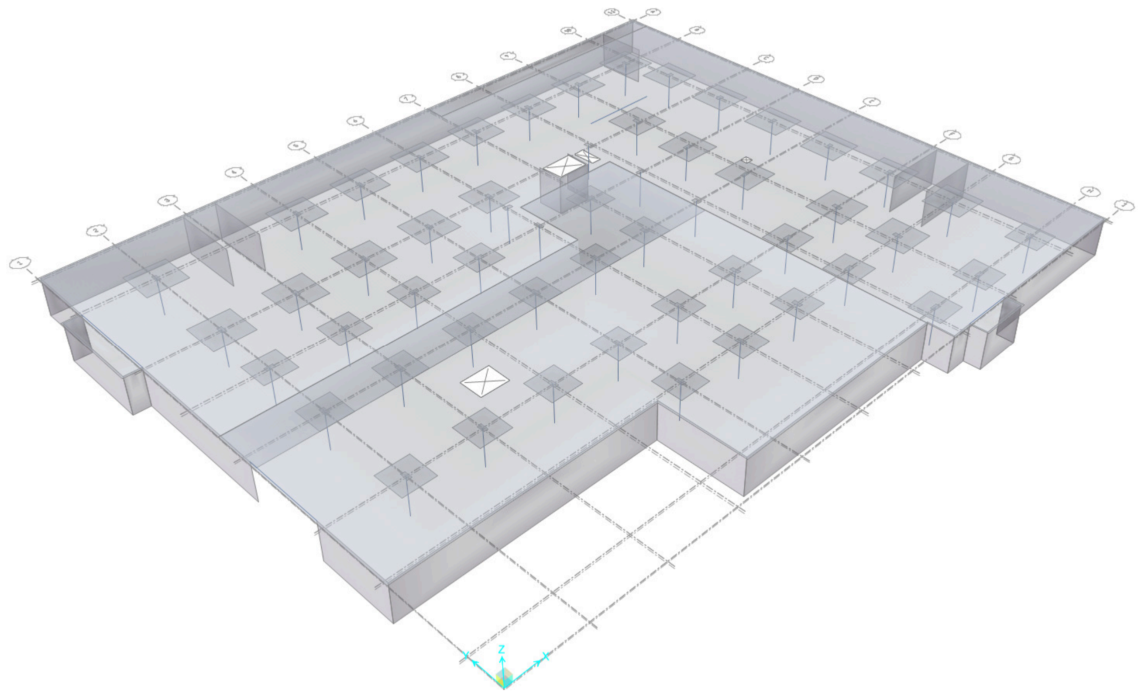


Figure 9 – Slab Modeling on CSI-SAFE Software

The analysis parameters for the armature calculation have been adjusted according to Figure 13.1 of CSA A23.3-04. The calibration is shown in the following figures:

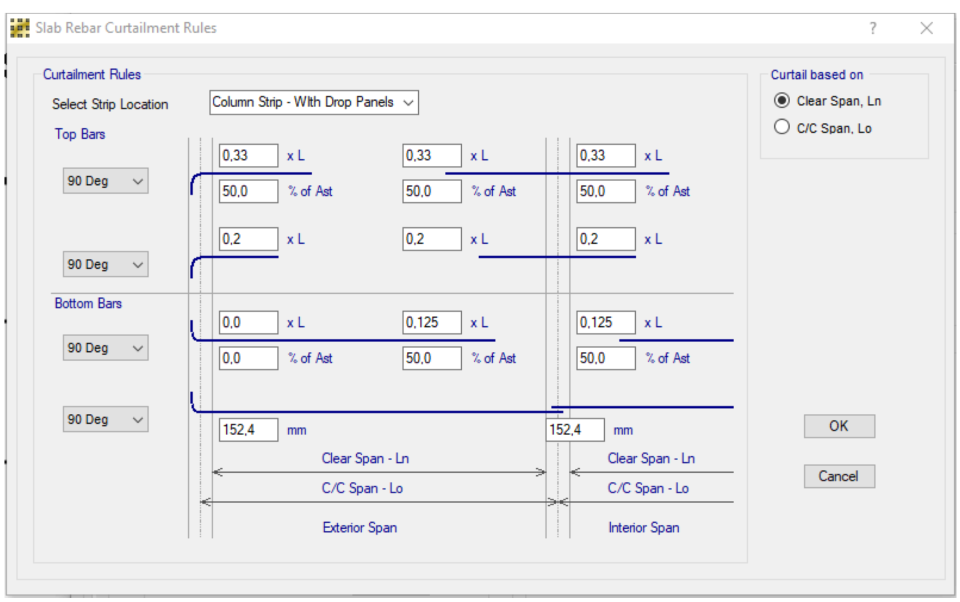


Figure 10 – Detailed reinforcement tape column

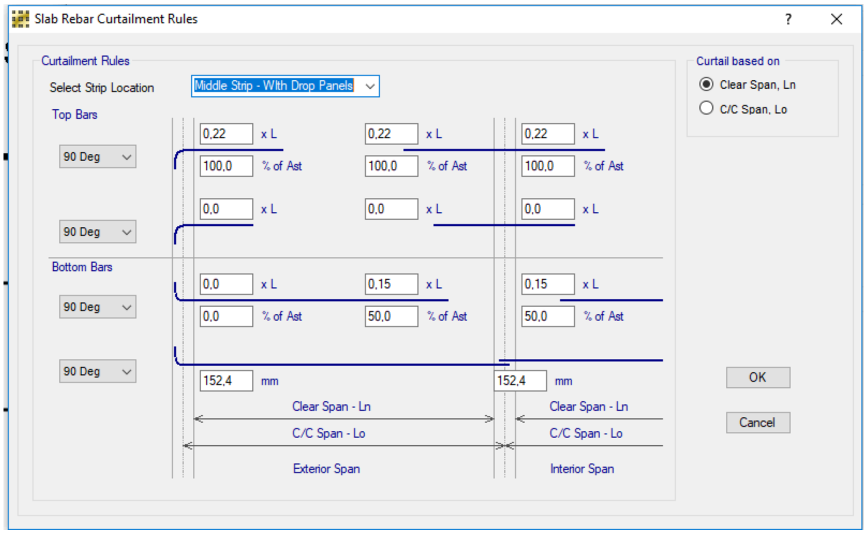


Figure 11 – Detailed reinforcement median band

The following three figures show the quantities of reinforcement recorded by SAFE for the three cases analyzed.

SR. NO	BAR SIZE	LENGTH(M)	WEIGHT(MTON)
1	15M	17559,180	27,56
2	TOTAL		27,56

Figure 12 – Tonnage of reinforcement steel slab GF 12 '' with concrete topping 1½ '' on the floors

SR. NO	BAR SIZE	LENGTH(M)	WEIGHT(MTON)
1	15M	16361,080	25,68
2	TOTAL		25,68

Figure 13 – 12 '' GF slab steel tonnage with FERMACELL product on the floors

SR. NO	BAR SIZE	LENGTH(M)	WEIGHT(MTON)
1	15M	17022,000	26,72
2	TOTAL		26,72

Figure 14 – 11 '' GF steel slab tonnage with FERMACELL product on floors

The following table shows the summary of concrete and reinforcement costs for the three cases analyzed. The last column shows the savings compared to case # 1.

Case	Description	Total steel tonnage	unit cost (reinforcement steel)	Steel cost	Concrete volume	unit cost	Concrete cost	Total cost	Savings
		(metric ton)	($ / metric ton)	($)	(m^3)	($/m3)	($)	($)	(%)
1	12 '' GF slab with 1½ '' lightweight concrete topping	27,56	1500	41340	465	130	60419	101759	-
2	12 '' GF slab with FERMACELL product	25,68	1500	38520	465	130	60419	98939	-2,77%
3	11 '' GF slab with FERMACELL product	26,72	1500	40080	426	130	55384	95464	-6,19%

Figure 15 – Summary Table of Concrete and Reinforcing Cost Savings

When calculating the steel in the slab, we get values between 3.46 pounds of reinforcement per square foot for case # 3 up to 3.71 pounds of reinforcement per square foot for case # 1. These values are lower than values calculated by a steel supplier. The ground floor and basement slabs of the benchmark building are constructed as of the date of issue of the report and the concentration of reinforcing steel obtained is closer to 5.5 pounds per square foot. The values of steel tonnage and cost are interesting for comparison between the cases studied. However, they cannot be used to estimate the actual amount of reinforcement of a building constructed.

The differences between the actual quantities of reinforcement and those calculated by a steel supplier can be explained by the fact that the software does not take into account the integrity reinforcement required for all the columns, it does not calculate the beam reinforcement and it does not calculate the reinforcements required for the punching of the slab, commonly called "shear head." In addition, a steel supplier includes support bar in its total weight in order to hold the 2 top frame rows. These bars are typically 10M to 20 " E2E.

The important figure in Table 5 is the saving percentage. In order to compare the different cases with each other, a monetary value was assigned to concrete and steel in order to obtain a "total cost" for comparison.

It is interesting to note that to maximize the material savings for the transfer slab, the engineer's judgment has a tremendous impact. If the thickness of the slab is not optimized, a large portion of the potential savings is lost. It is important to note that this thickness optimization is possible thanks to the load reduction caused by the replacement of the lightweight concrete topping by the Fermacell product.

Savings in the lateral load recovery system

The seismic loads of a structure are directly influenced by the mass of the structure. In the case of the use of the product for this project, a reduction of the building mass of 13% is evaluated.

	CONCRETE TOPPING 1-1/2	FERMACELL PRODUCT E31	DIFFERENTIAL
V_MSE (kN)	1173	1025	**13%**
Wall length EW direction (m.lin.)	124	124	
Wall length NS (m.l.)	110	110	
Medium Shear - Exact Calculation - EW (kN / m)	10.8	9.43	
Medium Shear - Exact Calculation - NS (kN / m)	13.5	11.8	

Figure 16 – Lateral Effort Assessment

In order to compare the reduction of lateral forces on wall partitions, a comparison with average shears per wall segment was evaluated. Therefore, in the case of the evaluated project, the use of FERMACELL 2E32 would have made it possible to use 2-OSB of 7/16 '' with an average nailing of 4 '' instead of 3 '' in the NS direction. However, in the EW direction, the reduction did not significantly reduce nailing. This reduction of lateral forces also makes it possible to reduce the wall jambs of the shear walls as well as the anchor brackets. These elements, however, have not been quantified in this study.

Soils are classified from A to F to represent their seismic location category. Category A corresponds to the best soil from a seismic point of view, while category F corresponds to the soil amplifying the effects of earthquakes. Earthquake load intensity is therefore directly related to the seismic site category of the site. For this reason, the Fermacell product becomes more and more interesting as the seismic class of the site is unfavourable. As part of the analysis of the project studied, a site class D was used. A worse class would have allowed a for greater savings related to the product.

Savings at the floor system and joists

By reducing the weight of the floors, beams or joists will necessarily be less loaded. There will be a decrease in the height, the grade of wood or the number of beams. In making the comparative analysis for a floor composed of open joists, it can be observed that for spans of less than 20'-0 '' the savings is mainly in the grade of the beams. On the other hand, for the ranges of more than 20'-0 '', a decrease in the height of the beams becomes possible. This decrease in height can result in significant savings in the building envelope. For example, for a six (6) storey wooden building with 28'-0 '' span joists, the building will be 10 '' lower. The savings in insulation, cladding and other components of the envelope will then be substantial. Here is a table of the savings of joist heights according to floor composition and range:

Scope	Beam Height (in)	
feet	Lightweight concrete toping	Fermacell
12	11.875	11.875
14	11.875	11.875
16	11.875	11.875
18	11.875	11.875
20	12.5	11.875
22	14	12.5
24	16	16
26	18	18
28	22	20
30	24	22

Figure 17 – Economic height of joists

For the design of the beams, an L/480 deflection under the overloads and L/240 for the total loads was considered. An absolute total deflection of 1 " (25 mm) was also considered. To reflect current industry practice, wood elements are limited to MSR 2100Fb grade and are spaced 16 " end-to-end.

Conclusion

The purpose of this expert report was to calculate the difference in material costs between the use of different floor composition for light-frame wood structures: the 1½ " lightweight concrete topping and the Fermacell product. For this comparative analysis, the analyzed building was a four (4) storey wooden building of 1525 m2 and one (1) concrete basement of 2280 m2.

This report indicates a potential 5% reduction in costs for foundations. At the structural slab, the potential cost reduction varies between 2.77 and 6.19% depending on the thickness of the chosen slab. Figure 14 illustrates a summary of the potential reductions caused by the use of the product.

	Case #1 (1½ " lightweight concrete screed)	Case #2 Fermacell product Slab 12 "	Case #3 Fermacell product Slab 11''
LOAD			
Floor Loads (lb / ft²)	530	503	490
Reduction (%)	-	**5.53%**	**7.93%**
FOUNDATION			
Reduction (%)	-	**5.00%**	**5.00%**
STRUCTURAL SLAB			
Steel (TM)	27.56	25.68	26.72
Steel ($)	41,340	38,520	40,080
Concrete (m³)	60,419	60,419	55,384
Total cost ($)	101,759	98,939	95,464
Reduction (%)	-	**2.77%**	**6.19%**

Figure 21 – Cost reduction at foundation and slab level

Regarding the potential gain on the seismic load resistance system, the potential savings are multiple and difficult to quantify. In a light wood frame building, the installation of seismic anchors is complex and a major source of work. Each element that will be reduced allows a reduction of the working time on the construction site and a faster closing of the walls.

There is also a possible saving in the floor joists and ultimately on the building envelope since the height of the joists can, in some cases, be reduced, which automatically decreases the height of the building.

The weight reduction achieved by using the Fermacell product can also impact other elements of the structure such as: load-bearing walls, wooden beams and wooden columns. These elements have been excluded from this report. To gain a more complete picture of hardware cost reductions, these elements will need to be assessed in another more comprehensive analysis.

Apart from all the points listed in this report, additional savings directly or indirectly related to the structure may be possible. Here are some examples.:

- The bottom wall plates will no longer need to be doubled to fill the height of the concrete screed, which decreases the amount of wood and reduces the drying shrinkage mainly caused by the reduction of the volume of the rails and sandpits;

- By decreasing the height of the beams, there will be a decrease in the envelope surface and outer cladding;

- If there are beams and columns inside the dwellings, these elements will be less loaded and will necessarily be of smaller size than under a concrete topping;

- The speed of execution can be increased since Fermacell dry screeds do not need drying cure;

- The humidity input into the building will be limited since the screeds are dry when they arrive at the site;

- All types of finishes are possible without the need for additional coating;

Finally, we would like to point out that much greater savings could be made if the reduction of the weight of the building by the use of Fermacell dry screeds avoids the use of deep foundations like piles or the use off structural concrete apron. A six (6) storey building with Fermacell dry screeds is only 10% heavier than a five (5) storey building with concrete topping.

The building was not chosen to benefit or disadvantage the Fermacell product. The analysis represents a concrete example where the Fermacell product could have been used to reduce the quantities of materials from the other structural elements on the project. The analysis is not a guarantee that savings can be replicated in all projects or situations and does not replace the expertise of a structural engineer.

Codes, Standards and References used

NRC - National Research Council Canada
National Building Code of Canada, 2010 (CNB)

CSA - Canadian Standards Association
CSA O86-09 – Engineering design in wood
CSA A23.3-04 (R2009) – Design of concrete structure