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UPC BARCELONATECH

“Estudio de optimización de costes para la restauración de edificios históricos basado en las experiencias de obra.”

“Optimization of price studies in the restoration of historic monuments based on feedback from construction site experience.”

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MASTER THESIS

THANKS

First, I would like to thank Pradeau Morin for offering me the opportunity to discover this enthusiastic sector of Historic Monuments. I would like to thank all those with whom I have worked during these 20 weeks for this internship.

I thank my training supervisor, Mr. Lionel Dague, for his confidence and for the knowledge. I also thank him for his availability and the quality of his coaching in business.

I also like to express my gratitude to Mr. Frédéric Létoffé, Director of the company, for the kind and warm welcome within the structure.

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Finally, I thank Mr. Guillaume CARPENTIER and Mr. Turmo, my study managers at the ESITC Caen and the UPC of Barcelona, for their advice and support during one of these six months.

ABSTRACT

This TFM aims to highlight the work of almost five months as a cost engineer in a company specialized in stone works for historical monuments. During this period, I had the opportunity to work on real projects, attend negotiation meetings and site visits. It was also the occasion to work for the rehabilitation and restoration of historical monuments, both in terms of vocabulary and intervention methods.

It was important to start the report with a state of the art through personal research on historical restoration: present the specific vocabulary to work on these structures attached to our heritage.

The second chapter will present the objective of the TFM with the development of a computer tool who will respond to the problem. First, we will see the resonances that will have allowed us to advance the computer tool chosen to focus on its development.

The first objective of the software tool created is to optimize the price studies that are currently carried out within the company. In addition, we will see that this tool will try to respond at the same time to the exposed problem and at the same time with other problems and with real needs of management control in a construction site.

Keywords:

Disbursed, HMO (hourly time of labour), DPGF (decomposition of the global price and lump sum), phase, patching, notebook, flow sheet.

RESUMEN

Este TFM tiene como objetivo destacar el trabajo de casi cinco meses como ingeniero de costes en una empresa especializada en trabajos en piedra para monumentos históricos. Durante este período, se tuvo la oportunidad de trabajar en proyectos reales, asistir a reuniones de negociación y visitas al sitio. También era la ocasión de trabajar por la rehabilitación y la restauración de monumentos históricos, tanto en términos de vocabulario como de métodos de intervención.

Se estableció importante iniciar el reporte con un estado del arte mediante una investigación personal sobre la restauración histórica: presentar el vocabulario específico para trabajar en estas estructuras adjuntas a nuestro patrimonio.

El segundo capítulo presentará el objetivo del TFM con el desarrollo de una herramienta informática que responderá a la problemática. Primero veremos las resonancias que habrán permitido avanzar la herramienta informática elegida para enfocarse en el desarrollo de la misma.

El objetivo primero de la herramienta informática creada es optimizar los estudios de precios que actualmente se realizan dentro de la empresa. Además, veremos que esta herramienta intentará responder al mismo tiempo a la problemática expuesta y al mismo tiempo con otros problemas y con necesidades reales de control de gestión en un sitio de construcción.

Palabras claves:

Desembolsado, HMO (tiempo de trabajo por hora), DPGF (descomposición del precio global y suma global), fase, parches, cuaderno, hoja de flujo.

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CHAPTER 1 :

THE STUDY OF HISTORIC

MONUMENTS

I Contexts and goals

I.1 Contexts of the internship

As part of my double degree course at the ESITC of Caen and the school of "Camins" of the Polytechnic University of Catalonia, I realize my final project of Master within the company Pradeau Morin – Historic Monuments, a subsidiary of Eiffage, as a trainee engineer in price studies. This 20-week internship started on June 17, 2019 and finished on November 01, 2019. As part of my training at the ESITC of Caen and the Polytechnic University of Catalonia, I had the opportunity to follow training in building and civil engineering (road, maritime, engineering structures). The courses that fascinated me the most during my last year of study were those dealing with the management of structures. The fact of being able to carry out my master thesis within "Pradeau Morin" allows me to work in practice on a subject which in theory fascinates me and at the same time to discover a trade still unexplored during my last internships.

The purpose of this Master thesis will be to understand and carry out the missions of a price studies engineer: during these four months a subject that can meet specific expectations of the company. The purpose of this subject will be to create a computer tool to optimize the work of price studies. The subject is entitled: "optimization of price studies in the restoration of historic monuments based on feedback from construction site experience.

I.2 Contexts and issues

The engineer in price studies at Pradeau Morin is responsible of the financial evaluation of a restoration project for a building classified as a Historic Monument in the region of Paris. The price studies engineer is required to analyse the contractual parts related to the market in order to set up and define methods, write technical documents, the provisional schedule and the constructive parts of the work.

Also, on the financial part, the price studies engineer establishes quotes, negotiates prices and determines costs on site (human resources and materials / materials required), attentive and aware of the progress of the site in order to readjust the costs for future and ongoing work.

I.3 Part of my intervention

Within the framework of the realization of my master thesis, my intervention focused on the price studies for the of Historic Monuments and I was under the supervision of Lionel Dague, price studies engineer for the company. The missions during my internship were :

- Analysis of market elements
- Definitions of methods implemented
- Realization of provisional schedules
- Consultations with companies (subcontracting) and suppliers
- Site cost estimates

My thesis also accompanied my engineering assignments in price studies. This subject will answer the problem set out in the previous part and the optimization of price studies in the renovation of historic monuments based on feedback from construction site experiences.

During the observation period, the needs within the company became more precise and described later.

II Presentation of the Company

II.1 EIFFAGE

II.1.1 The Organisation

European leader in concessions and building and public works, Eiffage operates through four divisions and seven businesses:

- CONSTRUCTION

“Eiffage Construction” works for all trades related to construction, development, property development and maintenance. These skills allow it to provide its clients with global expertise and a diversified offer. This entity includes “Eiffage Construction” but also “Eiffage Mobilier”.

- INFRASTRUCTURE

Eiffage Infrastructure works in the fields of road and rail construction, civil engineering, sanitation, earthmoving and metal construction. “Eiffage Infrastructures” carries out more than 30,000 projects each year. The Infrastructure entity includes “Eiffage Métal”, “Eiffage Génie Civil” and “Eiffage Route”.

- ENERGY

“Eiffage Energie” brings its expertise in electrical engineering, climate engineering.

- CONCESSIONS AND PUBLIC-PRIVATE PARTNERSHIPS

Eiffage Concessions is responsible for PPP work: Public-Private Partnerships. “Eiffage Concessions” has worked to build hospitals or TGV lines like the 182 km Brittany-Loire region.

II.1.2 Key organization

- 3rd construction group and concession in France, 5th European group
- Over 66,000 employees
- €15 billion in turnover in 2016
- 100,000 worksites
- 70 countries

II.2 Eiffage Construction

II.2.1 The different activities

- CONSTRUCTION

3rd French actor, “Eiffage Construction” covers, in new or in rehabilitation, all the products of the public and private sector.

- REAL ESTATE PROMOTION

“Eiffage Immobilier” is developing a diversified offer in close synergy with the “Eiffage Construction” teams.

- URBAN PLANNING

“Eiffage Aménagement” supports local communities in their development, whether for the restructuring of city centers or the creation of new neighborhoods.

- MAINTENANCE AND SERVICE WORKS

II.2.2 Key numbers

- 11,500 employees
- € 4 billion in sales
- 75% of turnover for Construction and 25% for Real Estate.

II.2.3 The Organisation in the region of Paris

“Eiffage Construction” is organized by market specialty in the region of Paris, with two regional departments (Private market and public market) and six specialized entities.

REGIONAL DIRECTION 1

- “*Eiffage Construction Habitat*”, specialized in the construction of social housing.
- “*Eiffage Construction Equipements*”, specializing in the construction and renovation of public equipment.
- « *Eiffage Construction Amélioration de l'Habitat* », specialized in social renovation.

REGIONAL DIRECTION 2

- “*Eiffage Construction Résidentiel*”, specialized in the construction of housing programs.
- “*Eiffage Construction Tertiaire*”, specialized in the construction of tertiary buildings and major restructuring of tertiary buildings.
- « Société Nouvelle Pradeau Morin », specialized in heritage renovation.

II.3 Pradeau Morin

II.3.1 Presentation

Founded in 1890, Pradeau Morin, centered in its beginnings on stone cutting, works for the renovation of the French heritage in all trades and achieves a turnover of nearly 75 million euros (data 2018). For 30 years, Pradeau Morin (formerly Pradeau Morin) has been part of the Eiffage group and continues to work for the conservation of the French heritage. Today, Pradeau Morin is made up of two entities: “*Pradeau Morin Rénovation*” for the renovation of luxury hotels and *Pradeau Morin Historic Monuments* in the restoration of historic monuments.

As part of their activities, Pradeau Morin has worked in recent years to:

- The restoration of the North tower of the Notre-Dame de Paris Cathedral (75004)
- The rehabilitation of the Hôtel Salé for the National Museum Picasso of Paris (75003)
- The conversion of the Grand Hôtel Dieu de Lyon (69002)
- The renovation of the Hôtel du Palais in Biarritz (64200)
- The restoration of the Court des Invalides in Paris (75007)
- The restoration of the palace Le Georges V (75008)

II.3.2 Pradeau Morin – Renovation

Heir to the Dumont-Besson company, builder recognized since 1868 for his emblematic achievements such as the Paris City Hall, the *Sacré-Coeur* church and the museum of modern art, *Pradeau Morin Rénovation*, formerly *Eiffage Construction Rénovation*. In the tertiary sector, *Eiffage Paris Patrimoine* or SOPAC, brings its know-how and expertise to its customers in the field of renovation and restructuring of office buildings, hotels and high-end residential buildings.

II.3.3 Pradeau Morin - Monuments Historiques



Figure 1- example of cut stonework - Pradeau Morin

As a Historic Monument (qualification 2194), the establishment has developed, since its creation in 1890, recognized know-how in heritage renovation, both in restoration of stone, brick or concrete facades and in heavy restructuring all trades or in closed and covered. The entity is also

involved in renovations and new buildings. The team is constituted of 60 people including 20 stonemasons qualified for the restoration of historic monuments. The establishment has a team of 20 stonemasons and 30 masons.



Figure 2- example of realizations - Pradeau Morin

With the 2194 qualification, the teams of the Establishment are qualified to intervene on works classified as Historic Monuments. Pradeau Morin Monument Historique is a member of the Groupement des Monuments Historiques (GMH). Frédéric Létoffé, director



of Pradeau Morin Monuments Historiques is also co-president of the GMH group.

II.3.4 Work in progress and recently realized by PMMH

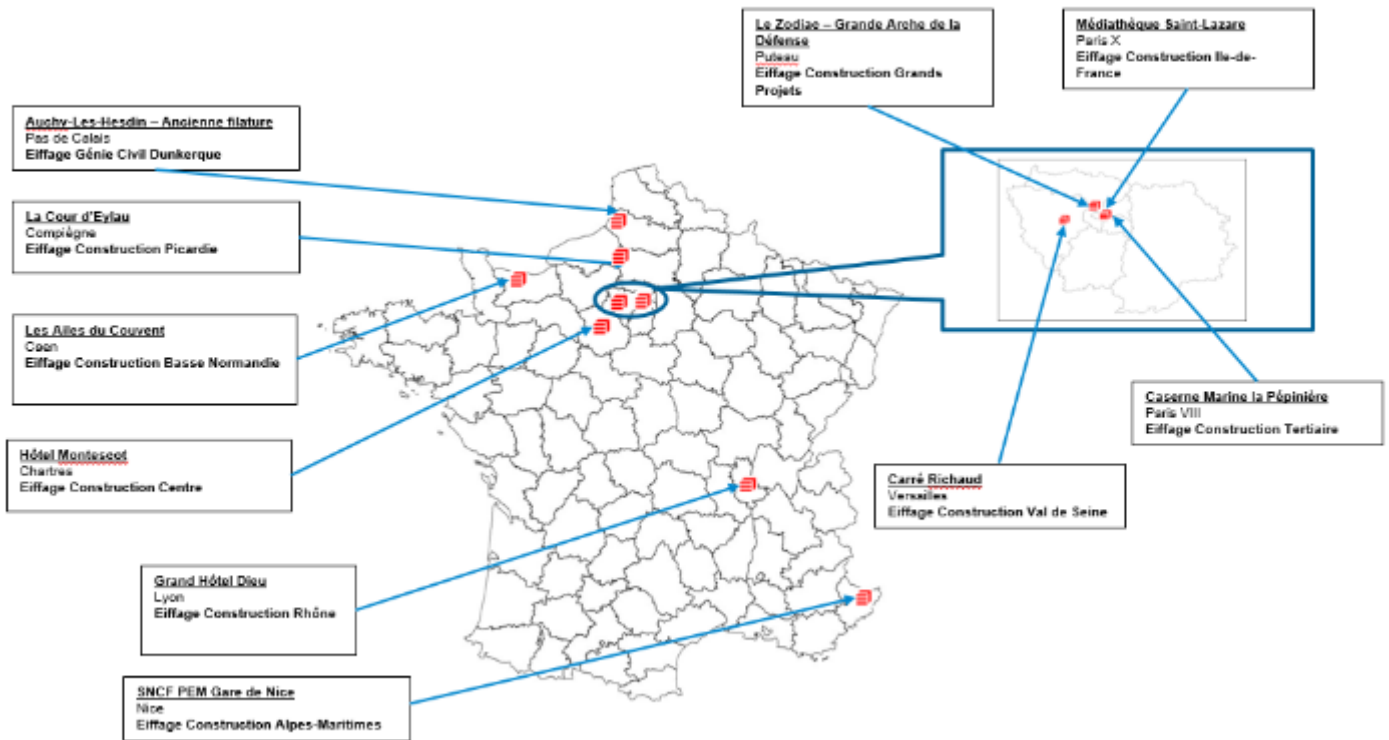


Figure 3- Localisation of construction sites - Pradeau Morin

III State of art – Stone structure

III.1 Introduction

Before even being able to detail my function as a trainee engineer in a company, which for more than a century has specialized in the restoration of historic monuments for stone cutting, it seems essential to introduce this report by personal research on stone cutting. This introduction makes it possible to establish a rapid historical reminder of stone architecture and to present the vocabulary specific to work on these structures attached to our heritage.

This state of the art is not only used to broaden its culture on specific methods used in construction; it is the synthesis of knowledge allowing approaching subjects of restoration of historical monuments.

III.2 The stereotomy

III.2.1 Introduction

The stereotomy or "stone cut" arrived in France significantly at the end of the first millennium by supplanting wooden construction. The first known works referring to stereotomy date from the 13th century but it was not until the 15th century that the first known stereotomy charter was born. A century later, the first "architect of the King", Philippe de l'Orme, changed the way of designing; construction is no longer something you learn only in the field, it is studied beforehand and becomes a science. In the 17th century, the profession of architect was finally recognized, and it was a century later that a detailed treatise on stereotomy was published. It was between the Renaissance and the end of the 19th century that stereotomy knew its age of glory and that every building worthy of the name was adorned with its stone element.

III.2.2 The vocabulary of stereotomy

III.2.2.1 The stone cutting



Figure 4- Stone cutting –
Colombes church

The stereotomy made it possible to pass the stone cutting to a mathematical practice. There are two types of size: the so-called "archaic" size and the "direct" size recommended by stereotomy. The "archaic" size consists in cutting the stone already in use. However, this technique can weaken the structure by the action of the tool on the stone. "Direct" cutting consists of making the final stone from the quarry stone, sometimes using an intermediate step using a "capable" block; pruning by "rendering".

III.2.2.2 The archs



Figure 5- Arch – Colombes church

Stereotomy proceeds significantly from the geometry of the circle. The broken arch or the basket handle are the combination of circles and are omnipresent part of the architect. The semicircular arches remain the most found stereotomy and the simplest to carry out; characterized by its semicircle geometry.

III.2.2.3 The arch segments



Figure 6- Example of an arch segment

Each stone in the arch is called a segment. The "box spring" is the first segment forming the arch and the "key" the last segment of the arch. The segments at the ends of the "key" are the "counter-keys". The other segments keep the name "segment". The part of the segment located inside the arch is called "the bow staves" and that outside: "the bow staves".

III.2.2.4 The cradles and flowerbeds



The cradles are the result of the creation of an arc over a shorter length. The most common arches (like the one shown opposite) are arches made from full hangers.

The flowerbeds are similar to cradles in upper surface staves but the lower surface staves are flat.

Figure 7- Roman flowerbed

III.2.2.5 The vaults



The vaults are the result of the crossing of two cradles of the same altitude. There are several types of vaults such as "edge vaults" and "cloister arch" vaults (opposite). The crossing of two flowerbeds of the same altitude forms a "flat arch". The crossing of two cradles of the same altitude in a box spring and of different altitude results in a vault in "priest's cap".

Figure 8- Vault and key vault – Colombes Church

III.2.2.6 The Structures



- *Structure en panache : the « tubes »*

The majority of structure *en panache* are tubes and made their appearance significantly in the 15th century. There are three main types of tubes: the spherical, cylindrical and conical tubes (Montpellier tube). If the tubes are still visible today, it is because they have for a long time saved space for the building but also enriched the exterior architecture of the house.

Figure 9- Example of structure *en panache* – Saint Sulpice Church



- *Spheric structure : the « cupolas »*

The cupolas (well represented in architecture) have long shaped Men by his relationship with the sky and thus the gods. There are multiple types of cupolas: "seated", "cul de four", "cloister arch", "helical".

Figure 10- Spheric structure – Colombes church



- *Helical structure*

Among the helical structures, we find biased bridges but also masterpieces of stereotomy like the "screw of Saint-Gilles". The screw of Saint-Gilles was built in the 12th century and consists of a circular cradle on a rising circular plane where the core is replaced by a helical stringer.

III.3 Stone damages

III.3.1 Introduction

The deterioration of stone buildings indicates the disorders affecting the stone. Since stone is a material that breathes, it evolves according to natural, accidental and human factors. In order to assess the measures to take - for the conservation or restoration of the building - it seems essential to know the causes of the alterations.

III.3.2 Natural factor

III.3.2.1 *The water*

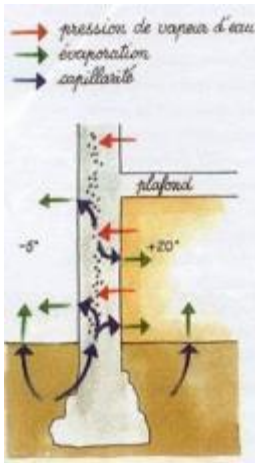


Figure 12- Damage due to water

Stone is by nature a porous material depending on the type. We distinguish porosity from porometry. Porosity is the ratio of the pore volume of the stone to the total volume. The more porous a stone, the more important the pore volume takes up in the stone. Porometry designates the ability of stone to retain water due to the diameter of its pores: this is the phenomenon of capillarity. Thus, depending on the porometry, a stone will be less subject to freezing than another will. In addition, this capillarity of the stone causes the elevation of underground water towards the walls, which bring with it the salts attacking the stone.

Among these strong salt containers, we find rainwater, which also attacks the stone by runoff, projections, etc. Finally, the humidity or water vapor discharges its salinity into the stone structures.

III.3.2.2 Chemical and biological mechanisms



Figure 13- damages due to biological mechanisms

Among the physical mechanisms most known and responsible for the degradation of the stone, the effect of the gel is sometimes heavy of consequence. In very cold weather, the volume of the stone can increase by 10% and cause deep cracks in the stone. We were talking about the action of water inside and on the surface of stones. This results in the accumulation of salts in the water. The salts - like sodium sulphate - accumulating in the pores will crystallize and disintegrate the stone: example of the alveolization of the stone or of the peeling of the stone (elimination of the layers of the stone). In addition, microorganisms present in the environment form algae and fungi and promote flaking degradations by producing sulfates.

III.3.2.3 Others factors

Other natural factors affect the structure such as the wind, which promotes the erosion of the stone or physical mechanisms such as earthquakes to a greater or lesser extent in certain regions.

III.4 Destructive and non-destructive methods of stone deformation

III.4.1 Introduction

In order to identify the disorders that have occurred in the stone (their nature and their evolution over time), methods of investigation must be implemented. There are two types of methods: "destructive" and "non-destructive". We will speak of destructive methods when these irreversibly alter the structure (coring, sampling). The non-destructive methods will be by contrast those which will spare the structure from any alteration.

III.4.2 Non-destructive methods

Among the non-destructive methods, vision remains the most primitive method but, in many cases, the most important in order to apprehend the pathologies of stone and structure. In addition, witnesses based on plaster or glass straddling a crack can reveal (approximately) the movements of the structure. In the 20th century, with the evolution of technological devices, the deformation records are more precise by the creation of:

- Radar and Scanner (metal detection).
- Radiography / radiography (gamma rays and X-rays).

III.4.3 Destructive methods

Among the destructive methods, for the most part they do not require a consequent alteration of the structure but very often the creation of a fine opening, which is filled in:

- Endoscopy (fiber optic observation)
- The ball extensometer (by moving two steel balls or placing a cylinder inside a facing)
- The inclinometer (by angular deformation)
- The acoustic extensometer (by electromagnetic vibration).

III.5 Measures taken on the structure

III.5.1 Shoring measures

The shoring measures are measures taken on a structure threatening with ruin in order to restore it a new stability and this, temporarily.

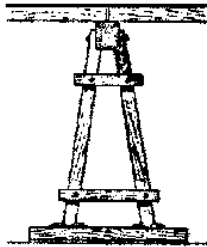


Figure 14-Candles

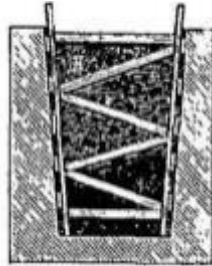


Figure 15- Struts

- **The candles.** They transmit vertical loads and are joined by struts giving it stability. Candles are used in the form of wood or steel.

- **The struts.** These are wooden structures placed in the openings.

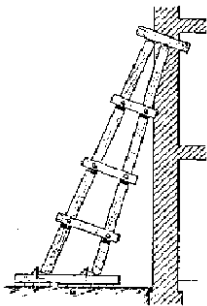


Figure 16- Buttress shoring and shrinking

- **Buttress shoring.** That support the weight of a structure and consist of three parts: the abutment (part on the ground), the lath (part in contact with the structure) and the strut itself.

- **The shrinking.** The act of tightening a forestay by a "hoop" like a metal belt starting from the same principle as the making of a barrel.

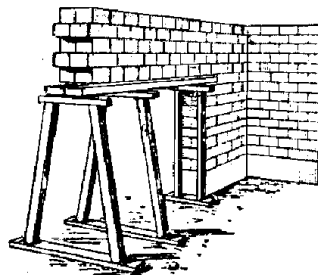


Figure 17- The headings

- **The headings.** In the form of wood or steel. Many used in the works in underlay., They allow to take again the efforts of a bearing work in order to be able to intervene on the pre-existing support. They consist of a part fixed to the work to be taken up and candles to ensure the resumption of loads to a box spring.



Figure 18- Hangers – Colombes church

- **The tie rods.** In wood, metal or composites. They are used to take up traction efforts. Often they are used in churches for emergency response due to the spread of books.

- **The hangers.** Shoring of arched structures (arches and vaults). Wooden trusses placed on stools on the ground. At the level of the intersecting ribs, the shoring requires the installation of half-hangers blocked between them by struts.

III.6 Curative measures

The curative works relate to the actions carried out on the work while not modifying neither the provisions nor their natures.

III.6.1 Types of stone

In order to be able to determine the curative measures on the stone, it is first necessary to know the characteristics and the natures of the stone. We will find on French territory different types of rocks with varying hardness:

Types of rocks:

- Sedimentary rocks (limestone, millstone, flint)
- Metamorphic rocks (shale, sandstone)
- Eruptive rocks (granite, basalt)
- Detrital rocks (molasse)
- Rocks from living organisms (tuff)

Rock hardness:

- "Soft" stone with a hardness between 1 and 4 (ex: Tuffaux, Pierre de Caen)
- "Firm" stone with a hardness between 4 and 8 (ex: Vernon)
- "Hard" stone with a hardness between 8 and 10 (eg Fontainebleau sandstone)
- "Cold" stone with a hardness between 10 and 13 (ex: Souppes)

III.6.2 Actions on masonry

III.6.2.1 *Actions against water*

The soils, being wet, excess moisture rises inside the masonry. Therefore, it is important to make the soil permeable and to allow the masonry to breathe. In order to limit the humidity of the soil to the right of the masonry, one of the most effective actions to achieve and avoid waterlogging of the soil. The easiest way to do this is to put a rainwater drainage system around the masonry. The tightness of the masonry could also be accompanied by "waterproof barriers" or "metallic or polyester sheets", which slip into the horizontal slots of the masonry. As well, the injection of a sealing resin is also carried out but may have gaps in its implementation with pores not filled with the resin. The water being loaded with salts and electromagnetic, it is possible to proceed by an electrophoresis and electro-osmosis sealing. This involves creating an electrical circuit inside the masonry that reverses the direction of water flow.

III.6.2.2 Cleaning on the front facing

Among the work carried out by a company specializing in stone construction, cleaning is an important task and must be done with respect for the material. Thus, it is important to carry out a diagnosis of the stone beforehand in order to determine the nature of the soiling of the stone.

The cleaning of the stone can be done by a method that does not require a liquid product. We can proceed by:

- Brushing; using compressed air on the facing
- Cut the stone. Take a few centimeters off the stone.

However, this technique has the disadvantage of both cutting out the material but also modifying the previous size effects and removing the patina layer.

- Abrasion. This method consists in projecting solid particles (aggregates) on the facing.
- Cryogenic projection. As with abrasion, we proceed by spraying dry ice.

Water cleaning

Stone cleaning can also be done with water. Water has the advantage of softening and removing the ash from the siding. We can proceed by:

- Semi-wet abrasion. Water spray on the siding. In order to avoid the impregnation of water in the stone, a suction system is put in place in order to recover the projected water directly.
- poultice. Rock wool added with hydraulic binder is sprayed. A tube system moistens the poultice drop by drop, which will be deposited at the end of the operation.
- Peel able. Application of a liquid product which binds to the facings and which is removed after drying. Very efficient and dust-free technique.
- Laser. More recently, laser cleaning has appeared which projects a very high intensity light ray causing microscopic dust vaporization. However, this expensive technique is only interesting on very small surfaces.



Figure 19- Example of cleaning facing – Madeleine Church



III.6.2.3 Repair on facing

We have previously seen some of the main factors responsible for weathering siding. It happens in many cases that the most exposed works (cornices, bands) are too damaged to perform only cleaning. An intervention to replace the structure is very often necessary. Among the known siding repairs:

- Repointing. Repairing the seals with the removal of the old seal and the implementation of a new one. The joints made for old buildings are based on lime mortar (aerial and hydraulic).
- Replacement of stones. Identical replacement of altered stones, always seeking to find a stone from the same quarry if possible.
- Reproduction of the Stone Cut. The tools and the implementation on the stones are as close as possible to the methods and knowledge of the time.
- Rubble. Replacement of part of the missing, altered or broken structure in the walls.
- Patching. When the weathered stone does not necessarily require replacement, we proceed by mortar levelling which is applied in thin layers in the voids.

III.6.2.4 Protections on facing

Coatings



Figure 19- Coatings - Compiègne

The coating has several vocations for the structure. The first one; it has the role of embellishing facades since it represents for many buildings a large proportion of these. Added with binders or fibers, it also has a structural function. It also protects structural elements such as rubble stone from the weather. The plasters consist - for the restoration of historic monuments - mainly of elements based on lime mortar or plaster.

- Lime

Lime results from the calcination of limestone after cooling in water. Lime once cooled generally waits 3 years before being added with sand and used on site.

- The plaster

III.6.3 Reinforcements and heavy restorations

III.6.3.1 *The foundations*

Since the foundations are underground, it is more difficult to examine and, in some cases, reinforce them. A strengthening of foundations is the cause of several factors:

- - Poor initial design of foundations
- - Modification over time of the characteristics of the foundations
- - Poor soil study
- - Change in soil over time
- analysis

In order to understand the disorders occurring at the level of the foundations, it is necessary to carry out an accurate analysis of the soils using recognized methods. These analyzes are carried out using direct measurements on site and in the laboratory:

- - Analysis of core samples (particle size and porosity)
- - In situ compressibility analysis
- - Plate test
- - Shear tests
- - Calculation of the weight of foundations
- - Recognition of the state of the foundations
- The intervention

According to the analyses carried out, a mode of intervention is determined. There are several types of reinforcement at ground level:

- - By injecting concrete grout under the foundations.
- - By clamping the floors with dark piles around the building.
- - By soil drainage.
- There are also types of reinforcement by deepening the foundations in search of good soil:
 - - By well. Extension of the foundations by making concrete pillars at the head of the foundations. Manually dug with diameters on the order of 1.50 meters.
 - - By piles and micropiles. Extensions of the foundations by concrete pillars made by mechanical drilling of diameters between 5 cm and 16 cm for micropiles and between 40 and 60 cm for piles.

Finally, types of reinforcements by widening are carried out:

- Widening of the soles by soles under foundations. Resumption of foundations by adding foundations under existing ones.
- Widening of the soles with moldy soles. Insoles placed at the foot of pre-existing foundations by embedding.

III.6.3.2 The masonry

Masonry and masonry restoration is the core business of a company like Pradeau Morin. Very often, the masonry is made up of not very noble materials such as rubble stones, pieces of stone, wood or mortars poor in lime. The supported loads are distributed randomly depending on the embodiment and the choice of materials. These random realizations resulting from disorders in masonry cause cracks.

The intervention



Figure 20- Grout injection

Grout injections. Technique consisting of injecting from the joints, a lime or cement grout which fills the pores and consolidates the masonry. Unfortunately, this technique is called "blind". Indeed, there is no precise means of control and implementation. Also, make sure that the grout does not leave the masonry towards the ends. Also, make sure not to pressurize the masonry until it breaks.

Chains. Iron tie rods and crampons inserted in masonry and stones in order to take up the forces following the overloading of the building or following the oxidation and bursting of the previous chaining

Recovery. Shoring of a structure (facade, enclosure) before straightening with iron rods



Figure 21- Chains – Colombes church



Figure 22- Recovery – St-Nicolas church

Replacing. Replacement of altered stones with healthy stones, identical and ideally from the same quarry and the same bench. Also, the technique used on the size of the stone should be done in respect of the types of sizes used on the monument.

IV Stone cutting units

IV.1 Introduction

Pruning work is paid in relation to the calculation of the lengths of plain facing and moulded facing of stone. Items that are not cut manually and not repetitively will be counted. The size of the stone will also consider the nature and difficulties of cutting the stone in addition to the calculations detailed below. Only sizes seen or covered with siding will be priced.

IV.2 Uniform facing

1. *Calculation of surfaces*

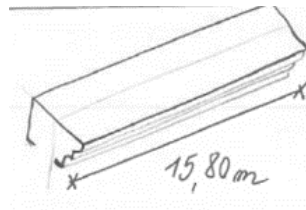
Example :

Support at the head of the wall:

- Length: 15.00 m
- Height: 50 cm
- Width: 30 cm

This support includes 5 flat faces and a moulded face. Among the planar faces, 1 is hidden (the one in contact with the wall). Thus, there remain 4 flat faces, 2 of which are ends of the support (played on the sides) and the top and outer faces.

Support at the head of the wall:



Calculation :

Top side and outside	$(0.5 + 0.3) * 15$	12 m^2
Corners	$(0.5 * 0.3) * 2$	0.3 m^2
	TOTAL	12.3 m^2

2. Determination of the stone cutting unit coefficient

Designation	Coef UTPU
Straight cutting not covered by siding	<u>1.00</u>
Straight cutting covered by siding	<u>0.5</u>
Cutting with simple concave/convex curve	<u>1.33</u>
Cutting with at least two concave/convex curve	<u>1.66</u>
Cutting for columnus	<u>1.50</u>
Bank cutting	<u>1.10</u>
Arches, openwork, structures with hooks, networks, gargoyles, etc.	<u>Entre 0.5 – 1.00</u>

3. Application/calculation of the UTPU

Multiplication of the cutting unit coefficient with the facing surface calculated in order to obtain the stone cutting unit.

Wall head support	12.5 m ²
Coef	1.00
UTPU	<u>12.5 U</u>

IV.3 Stone cutting units for moldings

1. Measurement of the lengths at the right of the mouldings multiplied by the unit coefficient of the cutting unit of moulded stone

Designation	Coef UTPM
Moulding on the right side	<u>1.00</u>
Moulding on circular part	<u>1.33</u>
Moulding on part with double curvature	<u>1.66</u>

- Additions are also to be added in order to consider the angles and corners (ends).

Addition provided by the meeting of the rectilinear parties	<i>Additional lengths</i> UTPM
Protruding angles	<u>+ 0.10 m</u>
Inward angles	<u>+ 0.15 m</u>
Depreciation	<u>+ 0.05 m</u>
Corner	<u>+0.05 m</u>
Addition provided by the meeting of the rectilinear parts with curvilinear parts	
Protruding angles	<u>+ 0.15 m</u>
Inward angles	<u>+ 0.225 m</u>
Depreciation	<u>+ 0.075 m</u>
Corner	<u>+ 0.075 m</u>

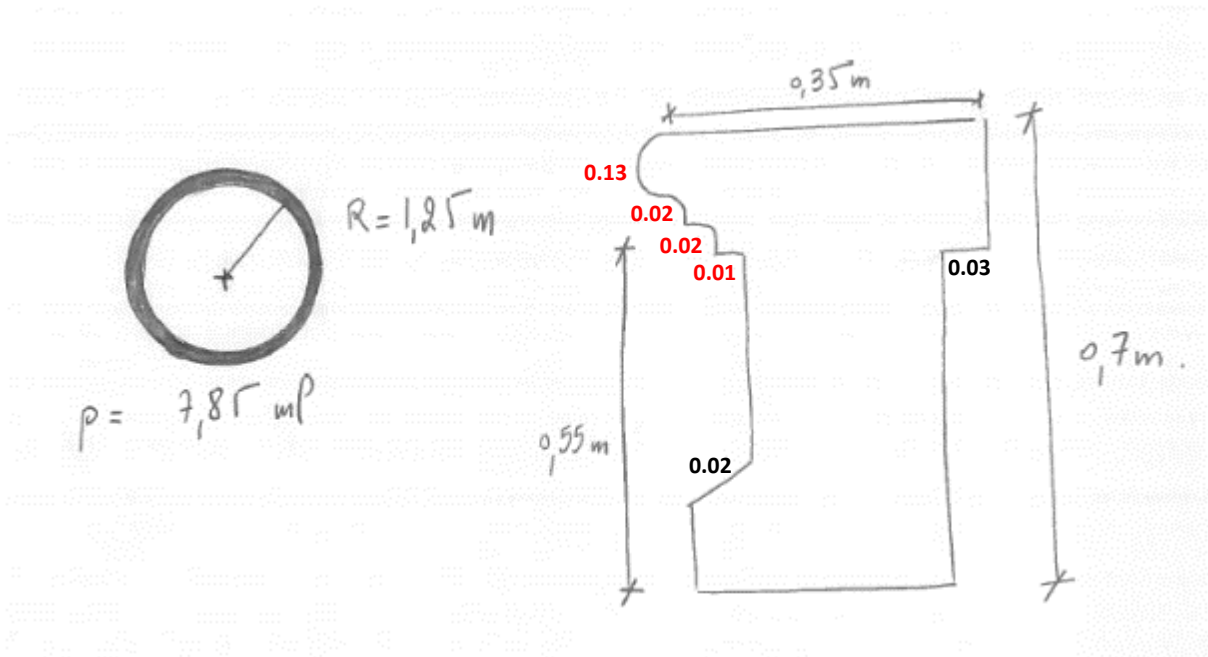
The lengths (developed) calculated above, the widths of the moulded profiles are multiplied according to the rule described below. They are distinguished in 2 types: flat bodies and curved bodies:

<i>Real lengths calculated</i>	<i>Used lengths</i>
<u>Flat moulders</u>	
< 0.075 m	0.075 m
> 0.075 m	Longueur réelle
<u>Curved moulders</u>	
< 0.10 m	0.15 m
$0.10 \leq l < 0.30$ m	Real lengths * 1.50
$0.30 \leq l \leq 0.45$	Real lengths * 1.33
> 0.45 m	Calculated as uniform facing

NOTA: slopes, listels without reworking, chamfers and slits are not mouldings and are therefore not calculated as such

IV.4 Examples

IV.4.1 Example 1 : Pool



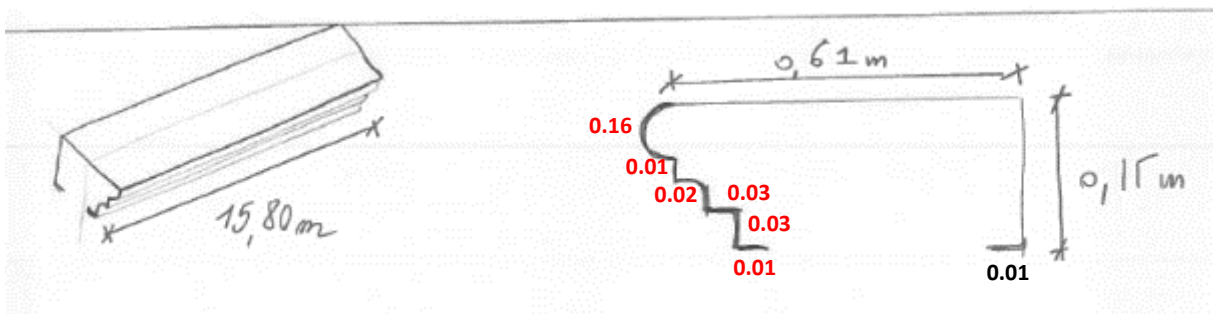
FACES	<u>TOP</u>			
	<u>0.35</u>	<u>0.35</u>		
	<u>OUTSIDE</u>			
	<u>0.55</u>	<u>0.55</u>		
	<u>INSIDE</u>			
SAILLIES	<u>0.7</u>	<u>0.7</u>		
	<u>CHANFREIN</u>			
(in black)	<u>TOTAL (ml)</u>	<u>1.6</u>		
	<u>0.02 < 0.075</u>	<u>0.075</u>		
	<u>REFEND</u>			
	<u>0.03 < 0.075</u>	<u>0.075</u>		
LENGTH	<u>TOTAL (ml)</u>	<u>0.15</u>	UTPU	<u>(1.6+0.15)*7.85*1.33</u>
	<u>TOTAL (ml)</u>	<u>7.85</u>		
COEF	<u>SIMPLE CURVE</u>	<u>1.33</u>		<u>TOTAL (U)</u>
	<u>(∅)</u>			<u>18.27</u>

TPM

<u>MOULDING</u>	<u>CURVED</u>	
(in red)	<u>2x 0.02</u>	<u>2x 0.15</u>
	<u>1x 0.13</u>	<u>1x 0.13x 1.5</u>
	<u>FLAT</u>	
	<u>1x 0.01</u>	<u>1x 0.075</u>
	<u>ANGLES</u>	
	<u>X1 RECT</u>	<u>1x 0.10</u>
	<u>TOTAL (ml)</u>	<u>0.67</u>

<u>LENGTH</u>	<u>7.85</u>		<u>UTPM</u>	<u>0.67*7.85*1.33</u>	
	<u>TOTAL (ml)</u>	<u>7.85</u>		<u>TOTAL (U)</u>	<u>7.00</u>
<u>COEF</u>	<u>SIMPLE COURBURE</u>	<u>1.33</u>			

IV.4.2 Example 2 : Coronation



<u>FACES</u>	<u>TOP</u>	
	<u>0.61</u>	<u>0.61</u>
	<u>OUTSIDE</u>	
	<u>0.15</u>	<u>0.15</u>
	<u>TOTAL (ml)</u>	<u>0.76</u>

TPU

<u>EXTREMITIES</u>	<u>CORNER</u>	
	<u>2x 0.61x 0.15</u>	<u>0.183</u>
	<u>TOTAL (ml)</u>	<u>0.183</u>

<u>MOULDING</u>	<u>CURVED</u>	
(in red)	<u>1x 0.02</u>	<u>1x 0.15</u>
	<u>1x 0.16</u>	<u>1x 0.16 x 1.5</u>
	<u>FLAT</u>	
	<u>2x 0.03</u>	<u>2x 0.075</u>
	<u>2x 0.01</u>	<u>2x 0.075</u>
	<u>ANGLES/CORNER</u>	
	<u>2x RIGHT ANGLE</u>	<u>2x 0.10</u>
	<u>2x CORNER</u>	<u>2x 0.05</u>
	<u>TOTAL (ml)</u>	<u>0.99</u>

TPM

<u>LENGHT</u>	<u>MOLDING FACING</u>	
	<u>15.80</u>	<u>15.80</u>
<u>COEF</u>	<u>RIGHT</u>	<u>1.00</u>
	<u>CORNERS</u>	
	<u>2x 0.61</u>	<u>1.22</u>
	<u>TOTAL (ml)</u>	<u>17.02</u>

<u>UTPM</u>	<u>0.99*17.02*1.00</u>	
	<u>TOTAL (U)</u>	<u>16.85</u>

IV.4.3 Results

	<u>UTPU</u>	<u>UTPM</u>	<u>TOTAL HOURS</u>
<u>EXAMPLE 1 : POOL</u>	<u>18.27</u>	<u>7</u>	<u>78.50</u>
<u>EXEMPLE 2 : CORONATION</u>	<u>13.38</u>	<u>16.85</u>	<u>123.00</u>

NOTA :

1 UTPU = 2 HOURS

1 UTPM = 6 HOURS

FOR A FLEXIBLE STONE

CHAPTER 2 : SUBJECT OF THE MASTER THESIS

V Presentation and preparation for the project

V.1 Introduction

A specific subject also accompanied my thesis in price studies. This subject will respond to the problem set out above either; the optimization of price studies in the restoration of historic monuments based on feedback from construction site experiences.

During the observation period, the needs within the company became more precise and described later.

The project will be realized according to a precise phasing. This phasing consists of five main points:

- 1st step: Observation of the situation
- 2nd step: Analysis of the problem
- 3rd step: Establishment of an action plan
- 4th step: Realization and follow-up of an action plan
- 5th step: Evaluation and results

The purpose of this part is to explain the progress of the tasks and stages carried out over 17 weeks of internship. To do this, we will rely on the schedule and details of the stages present in the phasing of the project.

V.2 1st step: Observation of the situation

- Previsional phasing : **2 weeks**
- Real progress : **3 weeks**

In this sub-section, we talk about the completion of the first stage of phasing as soon as a clear the analysis of the subject: (in introduction of the subject with my managers).

The first step of my internship was to understand the challenges of the job of a study engineer and that it differed depending on the company. Indeed, the mission of the price study engineer will not have the same repercussions on the purpose of the work in all companies (who checks the accuracy of his work?). One of the challenges of this first stage was also adaptation to the business. My adaptation was done very quickly since as of my arrival I was very well supervised and had to carry

out on my scale of tasks of engineer of study. Since the start of my PFE, I have been working under the supervision of my training supervisor for various tasks in the study phase:

- Constitution of files in response to a call for tenders in the public market
 - Analysis of market pieces
 - Realization of measurements
 - Consulting companies

- Classified facade restoration
 - Expertise and statement of damage on site
 - Realization of quotes

- Work after disaster
 - Intervention in meeting with experts (insurer, economist, contracting authority)
 - Adjustment of quotes
 - Intervention in negotiation meeting

Finally, this first part ended at the end of my third week of internship. Indeed, the subject of my end-of-study project had already been exposed in the second week but not clearly enough to start concretely the analysis of the different stakeholders and the identification of needs.

V.3 2nd step: Analyse of the problematic

- Previsional phasing : **3 weeks**
- Real progress : **2 weeks**

During a meeting bringing together the site managers of the company and the operations manager, it appeared (mainly) that the hourly workforce times defined in the study phase were not followed on site due to the difficulty of understanding the tables produced in the study.

- The first need is to simplify the understanding of the tables (DPGF, dry disbursement) made in the study in order to allow site managers a quick and simple reading of the planned workforce.

- The second need is the creation of a simplified site-monitoring table, which allows you to see the progress of the site in relation to the studies carried out.

To realize these needs, I mainly follow the restoration work on a set of buildings classified as historic monuments located in the Court of Eylau in a former staff school in Compiègne.



Figure 23- North wing north façade – Court of Eylau, Compiègne

During the following two weeks, I became interested in analysing the market and the work carried out in the study of the Court of Eylau. In addition, I went there to be able to chat with the site manager.

V.4 3rd step: Establish an action plan

- Previsional phasing : **3 weeks**
- Real progress : **3 weeks**

In order to establish an action plan, you must understand and analyse the problem: this is done in the second step. But also, you must make sure that expectations also respond correctly about the IEP. In fact, the needs must correspond to an optimization of the price studies based on feedback. Therefore, in discussion with my internship supervisor, we discussed the expectations of the company. The expectations are:

- Organize feedback with direct users of the future tools created (site managers and site managers) - 9 weeks
- Create a simplified tool gathering THMOs (hourly labour time) by activity. This will facilitate the visualization in the works phase of the credits allocated to each task. - Three weeks
- Set up a tool to make progress comparing the THMOs (hourly labour time) of the study phase and those of the work phase. - 4 weeks
- Ensure the reliability of the tool created and the response to needs - 7 weeks
- The production of practical files and explanatory files of the tools created to optimize price studies. - 7 weeks

Thus, in the sense that price studies have a real impact and make it easier to read at the start and during work, they are an added value for the company and are thus "optimized".

The IT tools at my disposal to carry out this subject will be:

- Microsoft office
- Autodesk software

The main tools envisaged for the accomplishment of the subject will be mainly Excel and Project software. Also, during these three weeks of reflection. I have gathered certain tasks that are part of the same activity group for the restoration of The Court of Eylau in Compiègne in order to free up several hours of labour and thus simplify their reading.

V.5 Phasing

1st step: Observation of the situation

- Integration and analysis of the company
- Observation and knowledge of the work of price study engineer

2nd step: Analysis of the problem

- Analysis and understanding of the actions of the various stakeholders
- Identification of business needs

3rd step: Establishment of an action plan

- Implementation of an action plan to respond to the problem of the internship
- Establish the objectives to be achieved
- Define the IT tool implemented

4th step: Realization and follow-up of an action plan

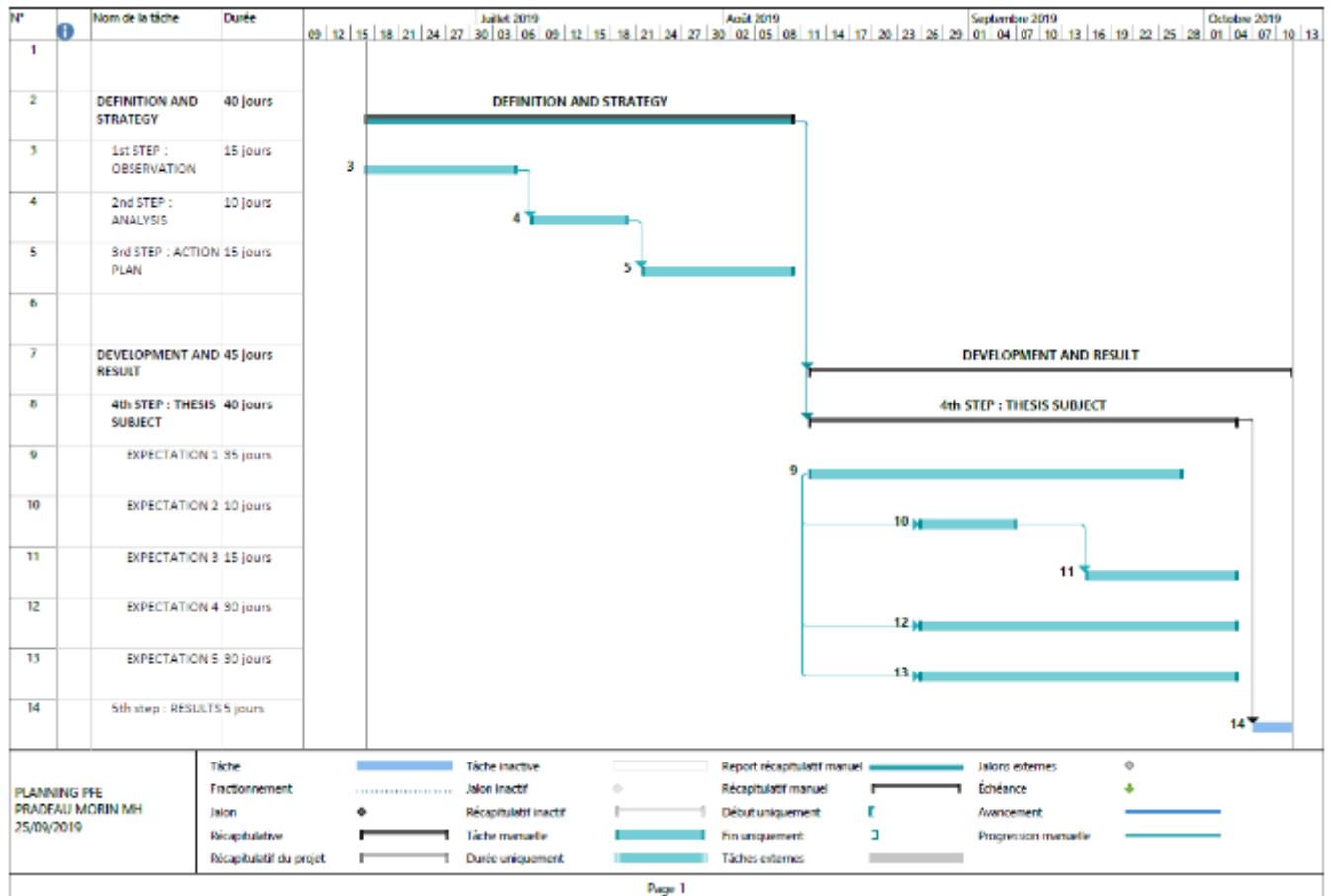
- Development of the action plan
 - Expectation 1: Organize feedback with direct users of the created tool (site managers and site managers)
- Monitoring and implementation of IT tools
 - Expectation 2: Create a simplified tool bringing together the THMOs (hourly workforce time) by activity. This will facilitate the visualization in the works phase of the credits allocated to each task.
 - Expectation 3: Put in place a tool allowing progress to be made comparing the THMOs (working hours) of the study phase and those of the work phase
 - Expectation 4: Ensure the reliability of the tool created and the response to needs.
 - Expectation 5: The production of practical files and explanatory files of the tools created to optimize price studies

5th step: Evaluation and results

- Establish a report that analyses the result of the IT tool created compared to expectations
- Allow the tool to be durable and functional
- Give a critical opinion to the IT tool produced
- Implementation of informative notes before and during the publication of the tools.
- Probable revision of tools to best adapt to users.

V.6 Previsional phasing

V.7 Risk analysis



A risk analysis must realize in order to measure the probabilities of failure of the expectations to be achieved.

RISKS	Probability [1-5]	Gravity [1-5]	Criticality
The schedule is not respected	2	4	8
Difficulty setting up feedback	2	5	10
Difficulties in setting up the tools	2	5	10
Lack of knowledge in the areas requested	1	4	4
Failure to create a database	4	2	8
The tool implemented does not meet the needs of the company	1	4	4
The tools have risks to its use	3	5	15

After analysing the table, we can see that the highest level of criticality is that of the risk incurred in using the computer tool. Therefore, to compensate for this, the creation of the tool will be supervised by my tutor and checked.

The probability of occurrence of the feared event varies between 1 and 5.

The severity of the feared event varies between 1 and 5.

Criticality<10	Negligeable
10<Criticality<20	Acceptable
20<Criticality<25	Inacceptable

Criticality translates here as the product of probability and gravity.

For a criticality level between 20 and 25, the risk is unacceptable. It is therefore important to take specific action to remedy this problem.

V.8 Conclusion

My integration into the company went very well and I was able to realize the profession of price engineer from concrete projects.

About the subject of the thesis, an understanding of the current needs of the company made it possible to redirect the problem towards the creation of tools which will make it possible to optimize the studies and works phases. These tools will allow a simplified reading of the work of the study teams towards the work teams but also the implementation of an advancement in the work phase based on the work carried out in studies.

VI Court of Eylau - Compiègne

VI.1 Introduction

The court of Eylau in Compiègne was built in 1783 in order to accommodate the royal stables. These stables develop on a regular plan around two courtyards and include among them the Hôtel de Luynes. In 1848, the Hotel was practically destroyed, and the site was abandoned. It was not until 10 years before, in 1858, an extension aimed at rebuilding the old area of the Hotel and the overvaluation of all the wings allowed the creation of a battle squadron which would become a staff school.



Figure 24- Cour od Eylau, Compiègne

VI.2 Chronology



The site consists of a set of small plots occupied by gardens and a few buildings.

East and South wing
 The buildings in the



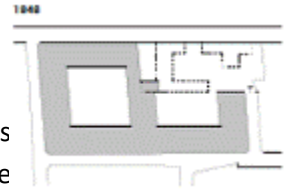
A royal ordinance envisages the creation of a district of cavalry. Creation of a "stock market district" for horses according to a regular plan and including a hotel: the Hôtel de Luynes.

courtyard.



Elevation of buildings

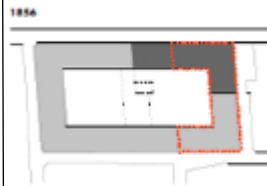
Destruction of buildings from the Hôtel de



extensions.

center are demolished and the complex

now meets around a rectangular



Après 1917

Demolition of the West Wing and later reconstruction.

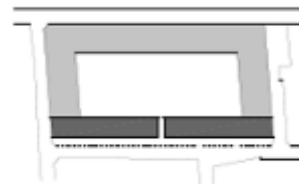


Figure 25- View of the court of Eylau nowadays

Stone studies

VI.2.1 Direct debits

To identify the stones in use from the court of Eylau investigations and samples of stones were carried out according to three types of samples:

Two types of samples requiring an in-depth study for classification:

- Samples on base stones.
- Levies on elevated stones.
- A type of stone sample identifiable with the naked eye:
 - Stone samples from the oldest area.

Several analyses complementary to the visual examination were carried out in the laboratory in order to determine the nature of the stones in work as well as their origin.

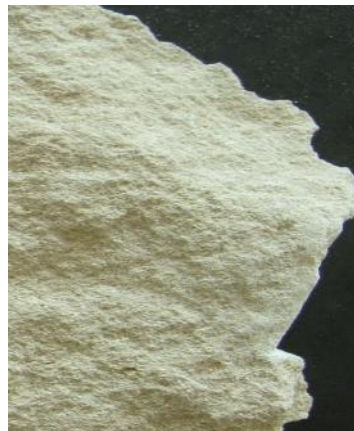
The different analyses focused on:

- A visual examination
- A study of the physical-mechanical characteristics for all samples:
 - Compressive strength
 - The density
 - The porosity accessible to water
 - The measurement of the ultrasonic propagation speeds achieved by transparency.

Sample A



Sample B



Sample C



VI.2.2 Condition of the stones

The stone facings have a certain number of alterations due to capillary rise and the presence of salts:

- Honeycomb areas
- Flaking areas
- Powdery powdery areas

In the basement: the stone facing - harder - (less prone to disintegration) and of saline origin has mechanical alterations: chips, cracks and cements.

VI.2.3 Identification of the stones

Sample A: Soft limestone sedimentary stone.

Sample B: Firm limestone sedimentary stone.

Sample C: semi-firm limestone sedimentary stone.

Direct debit A:

Clear ocher paste made up of limestone with "milioles", globigérines and nummulites also has physico-mechanical characteristics similar to Vassens fine stone. "Pierre de Vassens".

Debit B:

Fine-grained, clear paste made up of limestone with "milioles" and contiguous grains (compaction) also has physico-mechanical characteristics similar to the hard stone extracted from the quarry of Saint Maximin "Franche".

Direct debit C:

Beige paste, its fossil shells, its awakened structure and its physico-mechanical performances, has all the characteristics of Saint Maximin "Fine" stone.

VI.2.4 Conclusion

- Sample A : Stone of Vassens
- Sample B : Stone of Saint Maximin Franche
- Sample C : Stone of Saint Maximin Fine

VI.3 The intervention Pradeau Morin

Following the observation, the analysis of the stones and their condition, the Pradeau Morin company intervenes for the facade works of all the buildings of the Eylau courtyard:

- Hydro-scrub
- Plaster picking
- Patching
- Repair of joints
- Consolidation of masonry
- Replacement of weathered stones
- Stone cutting

In order to understand the work to be carried out on the facades of the buildings of the court of Eylau, I isolated two types of interventions: an intervention on a facade with stone cladding and a second intervention with a facade dressed in plaster.

The primary idea for the restoration of the facade is to keep the evolution of this building over time: the stone will either be refurbished or replaced, and the coated parts will be preserved. Thereafter, the client's wish was not to keep the coated coverings and to lay stone. We do not talk about it in this part but in the following chapters in order to explain the works as they were planned in the study phase.



Figure 26- Work in progress - Compiègne

VI.3.1 Façade with stone cladding

Works :

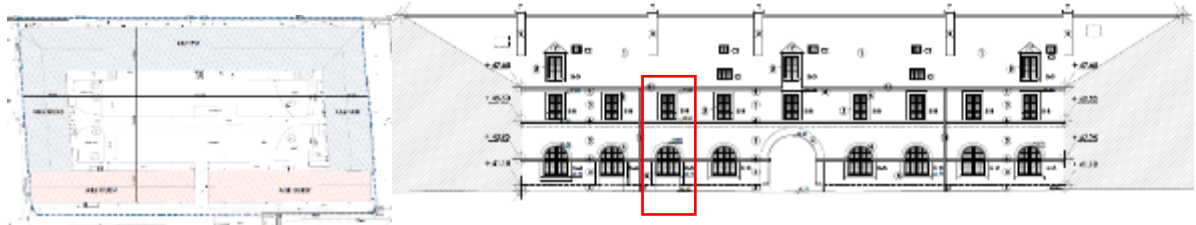
General cleaning of the facade by hydro-scrub.

Surveys, pitting and repair of the mass-tinted coating over the entire facade according to the shade chosen by the MOA.

On ashlar works: Restoration of ashlar facing. Replacement of stone and size on the existing, repointing and levelling with mortar your stone.

Whitewash of harmonization of tones on all the stone works of the facade.

Restitution of the splits on the window frames and doors.




Restoration of the stone frame: Stone replacement, levelling and repointing.

Surveys, pitting and refurbishment of mass tinted plaster.

Restitution of the split on the periphery of the bays

Restoration of the moulded strip and of the stone bay frame: Stone replacement, levelling and repointing.

Stone base, purging of composite screeds, stone replacement, screeds and repointing.



VI.3.2 Façade with coating

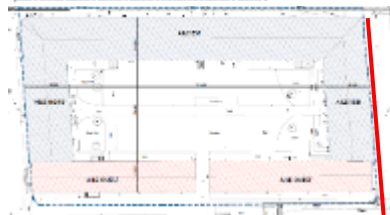
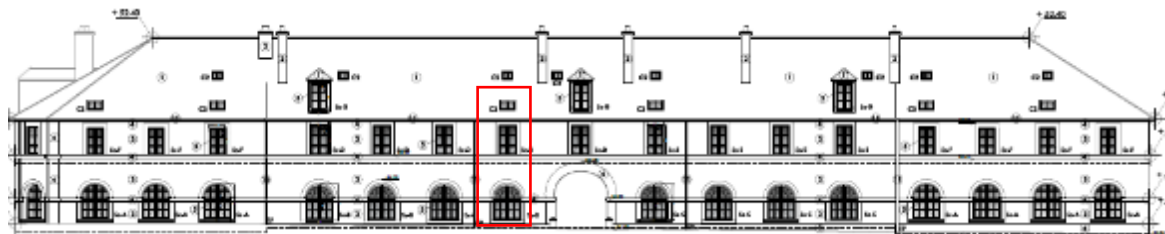
Works :

General cleaning of the facade by hydro scrub.

Surveying, digging and repairing the facing plaster in research and finishing by applying a micro mortar on all the plasters according to the shade chosen by the MOA.

On ashlar works: Restoration of ashlar facing. Replacement of stone and size of the existing one, repointing and resurfacing with your stone mortar. Whitewash of harmonization of tones on all the stone works of the facade. Restitution of the splits on the window frames and doors.

Removal of old obsolete works (downhill EP, electrical cabinet).



Restoration of the stone frame and the cornice: Stone replacement, levelling and repointing.

Surveys, drawing and restoration in search of plasters. Micro-mortar tinted in finish.

Restitution of the split on the periphery of the bays.

Restoration of the moulded strip and of the stone bay frame: Stone replacement, levelling and repointing.

Stone base, purging of composite screeds, stone replacement, screeds and repointing.



VI.3.3 Identification of the intervention

During the restoration, the parts of the stone facade retain their origins and those of concrete also as shown in the following drawings.

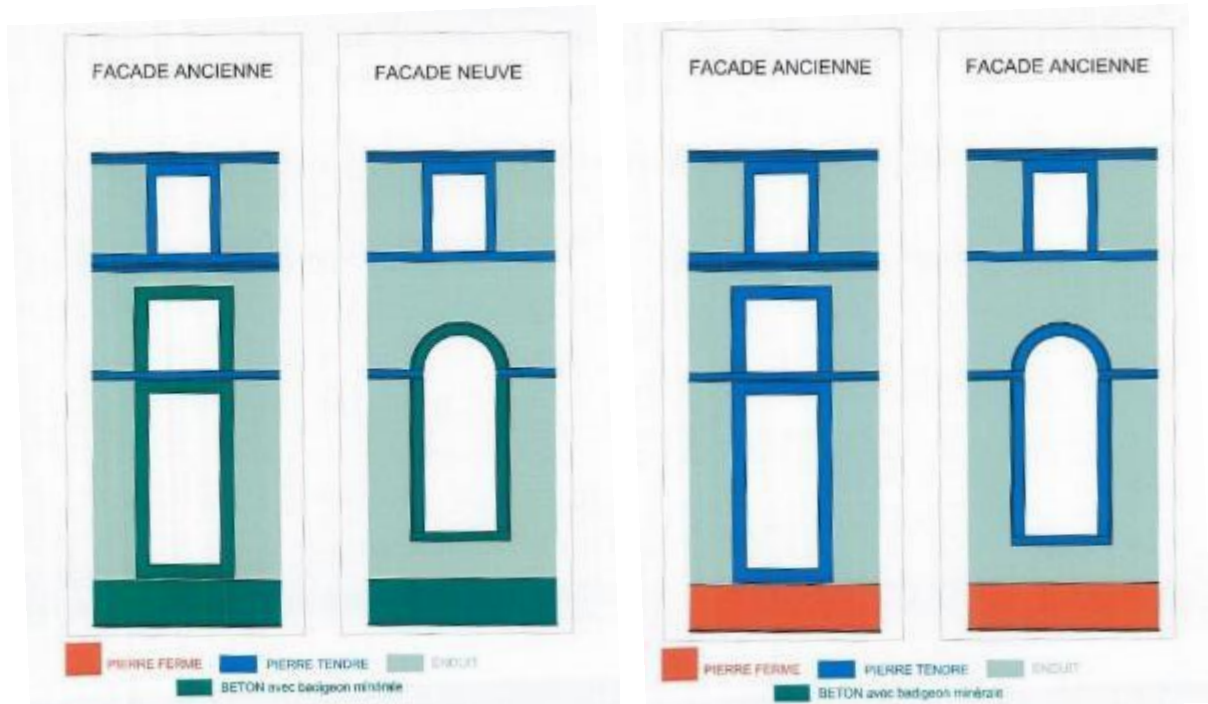


Figure 29- Comparison of old and new facades

VII Expectation 1 : Feedback

VII.1 Introduction

The first weeks will have allowed me to understand the company's policy and objectives. These weeks will also have allowed us to reflect on the development of the end of study subject.

Feedback is an essential step in the development of a controlled project. It was considered:

- To simplify the understanding of the tables (DPGF, dry disbursement).
- The creation of a simplified site-monitoring table.

To do this, before putting in place IT tools intended for a targeted audience, it is important to provide feedback that helps understand everyone's expectations. Thus, the feedback is spread over 9 weeks with 2 weeks entirely dedicated to it.

First, the feedback aimed to question the main stakeholders on the Compiègne site in order to adapt my results to the subject covered, but the feedback has widened.

VII.2 Feedback : Director

The subject of the PFE was precisely defined in consultation with the director of the structure and my project manager. It was essential for me to carry out this end of study project while respecting both the requirements of the school and the subject defined but also a pure desire to meet a real need of the company. Otherwise, the process would be bad. Following this meeting / consultation on the subject to be treated, I had the opportunity to carry out my study on a work in progress: the restoration of the Court of Eylau located in Compiègne. Indeed, it was during a meeting bringing together the site managers of the company and the operations manager that it appeared (mainly) that the hourly manpower times defined in the study phase were not followed on site due to the difficulty of understanding the tables produced in the study. The study of the Court of Eylau would allow me to answer on a specific case this revealed problem.

Expectation 1: simplification of the tables produced in the study phase transmitted to the site

This first request defined by the director of the structure is not direct in the sense that it is a request coming from the site managers. However, this simplification would allow the execution phase to be more consistent with the works sold and therefore to be able to manage the sites more effectively. This raised another problem: monitoring the site. Indeed, it would be interesting - in order to go further in the development of the first wait - to be able to implement the same IT tool which can be used both in the study phase and in the execution phase with a view to perfecting the progress of the work.

Expectation 2: creation of an IT tool allowing a study / execution link

VII.3 Feedback : study engineers

Within the Historic Monuments structure, two engineers carry out studies during the tender phase. Each of them has their own method of study and their own formatting of documents, notably tables (DPGF). In this case, my study on the simplification of the tables, for the sake of simplicity and consistency I will meet the expectations on the modification of the tables already used on the Compiègne site.

Regarding the understanding of the tables on site, everyone admits that the tables are not suitable for the execution phase and for site managers. Currently site monitoring is not properly linked to the studies. They therefore see a favourable opinion on the establishment of a table which would summarize the studies, and which is more suitable for site managers and site managers.

Expectation 1: creation of a summary sheet of their study sent during the execution phase.

Expectation 2: more consistency in monitoring operations between studies and execution.

VII.4 Feedback : Construction site engineers

The site managers oversee several sites at the same time and ensure good monitoring of the sites in coordination with the site managers. The follow-ups are mainly provided by the works supervisors with the establishment of tables which are based on the studies carried out without being linked to them. Thus, some data is lost between these two phases and the concordance of site monitoring cannot be done optimally. They are in favour of creating a simplification of computer tables allowing site managers to take a greater share in the progress of the site.

Expectation 1: creation of an IT tool in the study phase linked to their site monitoring.

Expectation 2: creation of a summary sheet allowing site managers to take a greater part in monitoring the site.

VII.5 Feedback : Compiègne

In order to get feedback on the Compiègne site but also to understand how it works, I went there 3 times at regular intervals of one month. During these visits, I carried out work progress and meetings with the site manager and the site foreman.

VII.5.1 Feedback : Construction site engineer – Compiègne : Olivier SEZILLE

Like his colleagues in charge of work on other sites, Olivier Sézille makes the same observation for the Compiègne site:

- The transition from study to execution is not optimal
- There are few links between the study and execution parts

Also, he regrets not having - depending on the size of the site - work carried out upstream in a more suitable way that considers a follow-up approach. In fact, current studies do not plan to simplify understanding or specific pointing of tasks.

Expectation 1: implementation of a sheet (Excel) to compare the hours planned and the hours worked on site (by task).

Expectation 2: create an IT tool to compare progress every month between what has been planned in the study and what is being achieved.

VII.5.2 Feedback: Site manager – Compiègne: Cyril DENIS

The site manager on Compiègne -Cyril Denis- is the manager within the company that knows the life of the site best. However, after having discussed with him, I realize that he has little readability or visibility on our studies. First, the disbursement table made in studies no longer reaches site managers since it is not adapted to them. These advancements and scores are made by hand and transmitted to the works manager.

Expectation1: simplification of the DPGF tables displaying the credits allocated by task.

Expectation 2: simplification of the DPGF tables displaying the remaining credits according to progress.

VII.6 Conclusion

The feedback has highlighted points already noted with the director of the company and my internship manager in the first weeks. He also highlighted problems concerning site monitoring: since site managers and site supervisors agree, we could improve the comparison of planned progress and actual progress.

VIII Expectation 2: Simplification of the THMO – draft of the computer tool

VIII.1 Introduction

The purpose of the IT tool is to meet the expectations set out during feedback. To do this, the development phase includes a phase of reflection on the IT tool to be implemented. Feedback must be obtained throughout the development of the project in order to be sure of correctly meeting the expectations of the stakeholders of the requested site. The development of the subject will be done along two axes. The first axis consists of responding to the wait called "Wait 2" which corresponds to the creation of a tool gathering hourly labour time (THMO). The second axis consists of responding to the expectation called "Expectation 3" which corresponds to the development and creation of an IT tool targeted at feedback.

VIII.2 THMO (Hourly labor time)

The first wait consists in setting up an Excel sheet isolated from the other sheets of the DPGF (breakdown of the overall and fixed price) carried out in study. The idea was, from the start, to be able to create a sheet called "RECAP" for site managers and works managers and which would resume from the sheets of the DPGF created hourly credits in front of the tasks at any time of the construction site. This sheet would be linked to the other sheets of the binder and would allow you to quickly see the hours credits allocated at the start of the work, the hours credits - in the form of additional work not planned during the basic study - and advancements. However, before that, it is necessary to understand how the site is organized and how it was sold.

VIII.2.1 Organizations of the DPGF

As stated during the presentation of the work, the major part of the intervention of Pradeau Morin's teams consists in restoring the facades by repairing or replacing the stone and coated elements (window frames, jambs, full hangers, etc.).

In order to facilitate the study, each facade is studied separately according to a set of buildings comprising a new part and an old part to be restored. In total, these are 4 wings to be studied, ie 8 facades and 2 porches. The works cited are located along the North / South / East / West directions. Among its orientations, the West zone has not been studied since it involves only so-called new work: on the new facade. The study and the tool created are only interested in works carried out on stone in restoration works.

On each facade, the paintings are organized according to three types of work:

- Preparation, cleaning, protection work
- Work on cut stones
- Masonry work

The works for which it would be interesting to simplify the task and credit hours sheets are works on ashlar and masonry. Below, I took the example of the detail of the work on the North Facade of the North Wing.

For cut stonework, there are almost 20 detailed tasks.

DESIGNATION	U	Qtés Entr	P.U	Montant HT	Options
AILE NORD FACADE NORD					
TRAVAUX DE BAVALEMENT					
Echafaudage de pied jusqu'à 1 m au dessus de la corniche (installation et dépose fin de chantier)				Lot 60	
Location échafaudage				Lot 60	
Sopline avec treuil électrique compris location	u	1,00	628,74	628,74	
Escalier extérieur				Lot 60	
Protection au droit des bases	m2	65,00	10,94	711,10	
Nettoyage des parements pierre de taille.	m2	233,00	15,54	3 620,82	
TRAVAUX DE PIERRE DE TAILLE					
Dépose des pierres en démolition	m3	30,60	1 409,95	43 132,23	
Fourniture de pierre neuve					
Pierre dure pour subsossement, seuil de porte	m3	12,00	2 370,54	28 446,48	
Pierre ferme pour encadrement de baie, bandeaux, corniche	m3	18,60	1 092,62	20 322,73	
Débit, taille et transport sur site des pierres neuves.					
Pierre dure pour subsossement, seuil de porte	m3	12,00	977,61	11 731,32	
Pierre ferme pour encadrement de baie, bandeaux, corniche	m3	18,60	875,38	16 282,07	
Pose de pierres neuves					
Fourniture, taille et pose d'une corniche neuve en pierre de taille sur la partie centrale de l'aile nord façade nord.					
(Travaux de charpente et couverture hors lot)	ml	37,40	858,12	32 093,69	
Ragréage mortier de chaux ton pierre (Forfait)					
Ouvrages moulurés de moins de 40cm ²	u	20,00	52,65	1 053,00	
Ouvrages moulurés de plus de 40cm ²	u	20,00	82,04	1 640,80	
Ouvrages unis de moins de 40cm ²	u	30,00	25,81	774,30	
Ouvrages unis de plus de 40cm ²	u	8,00	39,36	314,88	
Réfection des joints au mortier de chaux ton pierre	m2	110,00	50,09	5 509,90	
Sur les parements en pierre, badigeon d'harmonisation des tons au lait de chaux	m2	110,00	18,15	1 996,50	

Figure 30- Organization of the DPGF 1

Regarding masonry work; 6 sub-details.

TRAVAUX DE MACONNERIE					
Reprise des feuillures	ml	138,00	32,43		4 475,34
Reprise des rejets	ml	32,00	28,83		922,56
Joint de colfournement	ml	170,00	4,85		824,50
Fourniture et pose de maillons pour remallage.	m3	14,00	319,48		4 472,72
Coulis de chaux pour consolidation interne des ancienne maçonnerie de pierre.	kg	520,00	1,92		998,40
Plochement de l'enduit et refecton à neuf.	m2	453,00	108,09		48 964,77
TOTAL HT AILE NORD FACADE NORD				266 843,21	6 222,40

Figure 31- Organization of the 2nd DPGF

Opposite these sub-details, we find in the table of the company the hours allocated for each task

DESIGNATION	U	Qtés Entr	Montant HT	MD Manoeuvre	MD Maçon	MD TP	TOTAL MD Manoeuvre	TOTAL MD Maçon	TOTAL MD TP
Ragréage mortier de chaux ton pierre (Forfait)									
Ouvrages moulurés de moins de 40cm ²	u	20,00	1 107,40		0,90			18,00	
Ouvrages moulurés de plus de 40cm ²	u	20,00	1 725,80		1,40			28,00	
Ouvrages unis de moins de 40cm ²	u	30,00	814,50		0,40			12,00	
Ouvrages unis de plus de 40cm ²	u	8,00	331,20		0,60			4,80	
Réfection des joints au mortier de chaux ton pierre	m2	110,00	5 795,90		0,90			99,00	
Sur les parements en pierre, badigeon d'harmonisation des tons au lait de chaux	m2	110,00	2 093,90			0,28			30,80

(green area).

VIII.2.2 Simplification of the DPGF

In order to improve the readability of the hour's credits allocated, I started by redefining tasks in order to reduce the number and give them a better understanding. So, for stone and masonry work, I decided (in discussion with the site manager on Compiègne) to leave only 5 tasks in the new table:

- Supply, removal and installation of new stones
- Smoothing, repair of joints, lime grout, etc.
- Harmonization brush
- Supply and installation of rubble stone for remeshing
- Drawings of plaster

DESIGNATION	U	Qté à Entr	Montant HT	TOTAL		TOTAL	TOTAL	TOTAL	TOTAL
				Mtx	Mtl	MO Manoeuvre	MO Voiron	MO TP	TOTAL MO
FACADES ANCIENNES A RESTAURER									
AILE NORD FACADE NORD									
Fourniture, Dépose et pose des pierres neuves	mtx	1,00	196 157,28	48 737,00		209,30	1305,60	1248,00	2 762,70
Blochage, réflexion des joints, badigeon d'harmonisation, coulis de chaux pour consolidation, nettoyage des pierres, protection au droit des baies et fenest.	mtx	1,00	75 251,94	1 884,00		14,40	165,80	-	180,20
Sur les parois en pierre, badigeon d'harmonisation des linteaux et de chaux	m2	130,00	1 996,50	330,00				30,80	30,80
Fourniture et pose de modène pour corniches	m3	14,00	4 472,72	840,00			70,00		70,00
Pochement de l'enduit et réflexion à neuf.	m2	453,00	18 961,77			226,50			226,50
TOTAL HT AILE NORD FACADE NORD			264 843,21	51 791,00	450,00	1 541,40	1 278,60		3 270,20

Figure 32- Simplification of the DPGF

VIII.3 Advanced and additional works

After having simplified the DPGF with the reorganization of the tasks to make only 5, I was able to respond in a certain way to "wait 1" or in any case, I was able to bring a beginning of response. From now on, it is necessary to respond to the expectation concerning the monitoring of the site. For this, my site visits are accompanied by a marking of the tasks already carried out with at disposal a "notebook" (location of new stones to be changed) but also the location of all the stones and plasters according to the facades.



Figure 33- Marking of stones and plasters according to the facades (stones in red and coated in blue)

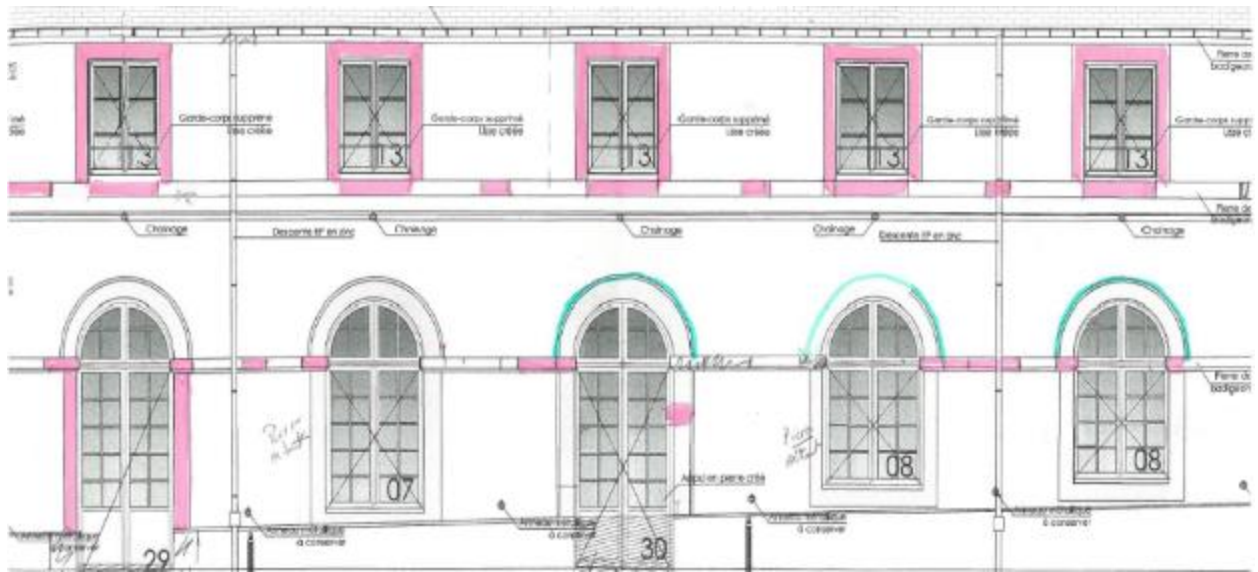


Figure 34- New stones notebook to ask

Once the tasks have been identified for the given date, I have set up an Excel sheet where I can report the quantities of stone to be changed and the levelling surfaces to be produced. Also, additional work having been requested later during the work, I set up the same type of progress table for the additional work.

	A	B	C	D	E	F	G										
1	AU1107/19		METRE RESTANT REEL		TOTAL PIERRE FERME RESTANT	21,6572 M3		BATIMENT	FACADE	TS A FAIRE							
2			CUBE		TOTAL PIERRE DURE RESTANT	5,1305 M3		NORD	NORD								
3																	
4																	
5		BATIMENT	FACADE	RESTE A FAIRE						FERME	BANDEAUX	ml					0,03
6		NORD	NORD	TYPE DE PIERRE	DESIGNATION	UNITE	QT				PLEIN CINTRES	u					0,294
7											JAMBAGE	ml	29,6				0,105
8				FERME	BANDEAUX	ml					LINTEAUX FENETRE R+1	ml					0,06
9					PLEIN CINTRES	u	4				JAMBAGE DE FENETRE R+1	u					0,102
10					JAMBAGE	ml					ENCADREMENT FENETRE R+1	u					0,2616
11					LINTEAUX FENETRE R+1	ml					PLACAGE	ml	17,44				0,2
12					JAMBAGE DE FENETRE R+1	u					APPUI DE FENETRE	ml					0,105
13					ENCADREMENT FENETRE R+1	u				DURE	SOUBASSEMENT	m²					0,1
14					PLACAGE	ml											TOTAL PIERRE FERME
15				DURE	APPUI DE FENETRE	ml	4										TOTAL PIERRE DURE
16					SOUBASSEMENT	m²	1,5										
17																	
18																	
19																	
20				RESTE A FAIRE						NORD	SUD						
21		NORD	SUD	TYPE DE PIERRE	DESIGNATION	UNITE	QT										
22										FERME	BANDEAUX	ml					0,03
23				FERME	BANDEAUX	ml					PLEIN CINTRES	u					0,294
24					PLEIN CINTRES	u					JAMBAGE	ml					0,105
25					JAMBAGE	ml					LINTEAUX FENETRE R+1	ml					0,06
26					LINTEAUX FENETRE R+1	ml					JAMBAGE DE FENETRE R+1	u					0,102
27					JAMBAGE DE FENETRE R+1	u					ENCADREMENT FENETRE R+1	u					0,2616
28					ENCADREMENT FENETRE R+1	u					PLACAGE	ml					0,2
29					PLACAGE	ml					APPUI DE FENETRE	ml					0,105
30				DURE	APPUI DE FENETRE	ml					SOUBASSEMENT	m²					0,1
31					SOUBASSEMENT	m²											TOTAL PIERRE FERME
32																	TOTAL PIERRE DURE
33																	

Figure 35- Progress table for work on stone and smoothing

VIII.4 « RECAP » Sheet

The purpose of the exercise is to set up a sheet called "RECAP" which can be easily understood by indicating the credits of hours remaining for the work. Thus, I set up the table below comprising the 5 reorganized tasks (plus a new task arrived for additional work which is the plating) according to their hours credited at the start of the site and progress to date given (including additional work).

DESIGNATION	TOTAL MO DEVIS DE BASE	TOTAL MO TS DE BASE	TOTAL MO RESTANT AU 05/09/19	TOTAL MO TS RESTANT AU 05/09/19
AILE SUD FACADE SUD				
Fourniture, Dépose et pose des pierres neuves	907,30	112,48	549,94	2,70
Ragréage, réfécation des joints, badigeon d'harmonisation, coulis de chaux pour consolidation, nettoyage des pierres, protection au droit des baies et treuil Sur les parements en pierre, badigeon d'harmonisation des tons au lait de chaux	230,70		45,95	4,88
Fourniture et pose de moellons pour remallage.	33,04		16,80	2,10
Réfécation de l'enduit: piochage complet et réfécation à neuf.	60,00		25,00	
Placage	146,95			270,00
TOTAL HT AILE SUD FACADE SUD	1 377,99	112,48	637,69	279,68
AILE SUD FACADE NORD				
Fourniture, Dépose et pose des pierres neuves	412,55			
Ragréage, réfécation des joints, badigeon d'harmonisation, coulis de chaux pour consolidation, nettoyage des pierres, protection au droit des baies et treuil Sur les parements en pierre, badigeon d'harmonisation des tons au lait de chaux	223,38		4,20	
Fourniture et pose de moellons pour remallage.	52,08		4,20	
Réfécation de l'enduit: piochage complet et réfécation à neuf.	7,50		7,50	
Placage	74,40			
TOTAL HT AILE SUD FACADE NORD	769,91	-	15,90	-
AILE EST FACADE EST				
Fourniture, Dépose et pose des pierres neuves	741,45	2 292,92	300,54	460,21
Ragréage, réfécation des joints, badigeon d'harmonisation, coulis de chaux pour consolidation, nettoyage des pierres, protection au droit des baies et treuil Sur les parements en pierre, badigeon d'harmonisation des tons au lait de chaux	166,85		156,68	219,05
Fourniture et pose de moellons pour remallage.	16,51		14,84	9,94
Réfécation de l'enduit: piochage complet et réfécation à neuf.	62,50		62,50	77,50
Placage	379,53		11,25	
TOTAL HT AILE EST FACADE EST	1 366,84	2 292,92	545,81	1 721,96

Figure 36- RECAP

VIII.5 Conclusion

It was initially planned during the design of these tables to achieve something that would be used in a sustainable way on construction sites and that it would be the subject of my PFE. However, the approach described remains simple and it is not all completely intuitive. Also, the time spent advancing is both laborious (hand-copying and no link between the tables) but also imprecise. Therefore, I will expose in the part which follows the realization of an Excel workbook which takes example of the current workbook while being much more advanced and playful.

IX Expectation 3 : the informatic tool

The drafting of a computer tool presented before allowed me to understand the challenges of such a tool and gave me time to reflect on several areas for improvement. Since the primary desire was to do something simple and effective for the advancement of the site, with this notion of monitoring studies, I wanted, and it seemed more appropriate to create a single workbook that would be used in study and on site.

This filing cabinet includes six different sheets which will be completed either by the study parties or by the site managers (site managers and site managers).

IX.1 Debit sheets

In the study of the draft creation of the computer tool, the concept of advancement is not taken enough into account. Indeed, for an advancement to be as precise as possible, it is either to carry out the study as far as possible (according to the time allowed). To do this, I decided to integrate into the created workbook the exact quantities of stones changed for the work (I remind here that my study concerns the creation of a computer tool for cut stonework).

Currently the debit sheets are made by hand using notepads which are also made by hand or on AutoCAD (by hand here). The stone notebook is in the form of a facade plan where the site manager or / and the site manager specializing in cut stonework comes to identify excessively weathered stones that need to be changed.

Operations carried out by the Site Manager / Works Manager

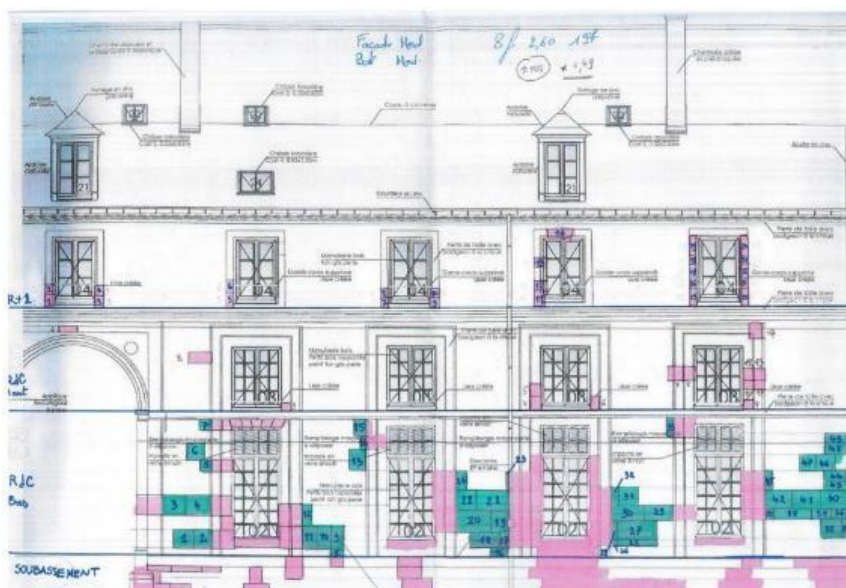


Figure 37- Notebook for locating stones to be changed

Each stone is then numbered, and their dimensions are reported in what is a debit sheet. Depending on the expertise of the stones, each stone is also defined for its origin or type.

The idea is to create a sheet called "Debit sheet" in which the works manager or site manager will have the possibility of entering his debit sheets in Excel.

For the sake of practicality, these are two sheets which are created in order to be able to differentiate between the works sold which have been planned on the market and the additional works.

Operations carried out by the Site Manager / Works Manager

MARKET								
FAC ADE SUD	SOUTH FACADE		LENGTH	DEPTH	HEIGHT	AREA	VOLUME (m³)	STONE
	N°	T1						
1	T1	1	26	15	20	0,052	0,008	SAINT MAXIMIN BANC 3
2	T1	2	20	20	18	0,036	0,007	SAINT MAXIMIN BANC 3
3	T1	3	17	15	34	0,058	0,009	SAINT MAXIMIN BANC 3
4	T1	4	33	20	25	0,083	0,017	SAINT MAXIMIN BANC 3
5	T1	5	50	15	26	0,130	0,020	SAINT MAXIMIN BANC 3
6	T1	6	50	15	16	0,080	0,012	SAINT MAXIMIN BANC 3
7	T1	7	56	15	26	0,146	0,022	SAINT MAXIMIN BANC 3
8	T1	8	30	15	26	0,078	0,012	SAINT MAXIMIN BANC 3
9	T1	9	47	15	32	0,150	0,023	SAINT MAXIMIN BANC 3
10	T1	10	39	15	26	0,101	0,015	SAINT MAXIMIN BANC 3
11	T1	11	33	15	22	0,073	0,011	SAINT MAXIMIN BANC 3
12	T1	12	30	20	28	0,084	0,017	SAINT MAXIMIN BANC 3
13	T1	13	48	15	34	0,163	0,024	SAINT MAXIMIN BANC 3
		T1C						
14	T1C	1	27	15	27	0,073	0,011	SAINT MAXIMIN BANC 3
15	T1C	2	60	15	27	0,162	0,024	SAINT MAXIMIN BANC 3

Figure 38- Market debit sheets

IX.2 « Tasks » sheet

La The realization of the "tasks" sheet builds on the work that was done before and exposed in the previous part. This sheet called "task sheet" aims to be a lean database for stonework. Thus, this database aims to be reused and I hope that it will be further optimized in order to make it smarter (more complete but also closer to reality).

For this first case and this first realization of a data bank, I adapted the hours to be credited to the tasks according to the information that I had obtained in consultation with my colleague at the price studies but also the information obtained on site with the chief site.

We will find - for example - two types of picking: a picking on rubble stone and a picking on brick (two types of picking that we find on Compiègne). In the study phase, the hours credited for drawdowns do not consider the nature of the structure behind the plasters (which posed a problem).

Operations carried out by the design engineer

	REMARKS	DESIGNATION	h/U	MO Manœuvre	MO Maçon	MO TP
<u>1</u>	TASK 1	SUPPLY, REMOVAL AND LAYING OF STONES SAINT MAXIMIN RIGHT	m³	26	26	14
2						
3	*	DEPOSITION OF DEMOLITION STONES	m ³	13	13	
4	*	INSTALLATION	m ³	13	13	
5	*	FLOW, SIZE AND TRANSPORT OF STONES	m ³			14
6						
<u>7</u>	TASK 2	SUPPLY, REMOVAL AND LAYING OF STONES SAINT MAXIMIN COLONNE	m³	0	0	0
8						
9	*	DEPOSITION OF DEMOLITION STONES	m ³			
10	*	INSTALLATION	m ³			
11	*	FLOW, SIZE AND TRANSPORT OF STONES	m ³			
12						
<u>13</u>	TASK 3	LIME MORTAR CONSOLIDATION	kg	0,03	0	0
14						
15	*	LIME MORTAR CONSOLIDATION	kg	0,03		
16						
<u>17</u>	TASK 4	JOINING LIME	m²	0,6	0,9	0
18						
19	*	JOINING LIME	m ²	0,6	0,9	
20						
<u>21</u>	TÂCHE 5	RECOVERY CEMENT JOINTS	m²	0	3,35	0
22						
23	*	RECOVERY CEMENT JOINTS	m ²		3,35	
24						
<u>25</u>	TASK 6	PICKING OF PLASTERS	m²	0,93	0	0
26						
27	*	piochage	m ²	0,65		
28	*	CLEARING	m ²	0,28		
29						
<u>30</u>	TASK 7	MOELLONS LANCES	u	0	0,25	0
31						
32	*	SUPPLY AND LAYING OF MOELLONS	u		0,25	
33						
<u>34</u>	TASK 8	COATED	m²	0	1,7	0
35						
36	*	LIME COATINGS ON MOELLONS	m ²		1,7	
37	*					
<u>38</u>	TASK 9	COATED PATINA	m²	0,18	0,18	0
39						
40	*	COATED PATINA	m ²	0,18	0,18	
41	*					

Figure 39- Tasks sheet

IX.3 The location sheets

The so-called identification sheet does not take this name except that of the location of the work when the building in question is divided by area. On the Compiègne site, 6 mark sheets will therefore be created for each facade of the building to be restored. For the creation of the tool, I isolated my study with a single facade which is the North facade of the North wing.

These sheets of the workbook concentrate several information which will be detailed later. Let's go back to the flow sheets and the link they have on these tracking sheets. The debit sheet corresponding to the North facade of the North wing and reported in the location sheet of the North facade of the North wing. We find in the sheet "North Facade North Wing" the debit sheets Market and TS (additional works) with for information the designations of the stones, their dimensions and their type.

Operations carried out automatically and verified by the design engineer.

PIERRES NEUVES											
MARBRE						TS					
ALLI Nord FACADE Nord											
DESCRIPTION	Quantité	Longueur	Largeur	Épaisseur	PROG	PROG	PROG	PROG	PROG	PROG	PROG
T1	1	0,310	0,310	0,300	0,020	0,000	0,000	0,000	0,000	0,000	0,000
T2	2	0,340	0,340	0,300	0,020	0,000	0,000	0,000	0,000	0,000	0,000

Figure 40- Debit sheets linked to advancements

We also notice two other pieces of information for each stone which are: supply and progress. In fact, each stone is linked - in addition to the flow sheet - to a control box in which it is possible to manage the progress of the stone.

The control box will indicate for each stone if it has been:

- Supplied
- Posted
- Finished
- Tabled

Operations carried out by the Site Manager / Works Manager

T1 - 1 PROVIDED

_____ ▾

New stone box control

T1 - 1 PROVIDED

_____ ▾

DEPOSIT

LAID

FINISHED

For each stone present in the debit sheet, a control box is created and is affiliated with the stone in question. The interest in creating playful control boxes was to allow the site foreman to be able to easily make a move. In order to make the tool even more visual, the first idea is to be able to display the stone notebook in this location sheet. Thus, once the notebooks have been made, each control box previously affiliated with its stone can be redirected in front of its stone on the notebook. To illustrate this, I take the example of part of the North Wing North façade. For which I was interested in the study of stones in R + 1 planned for the market and in the DRC planned for additional work.

Operations carried out by the Site Manager / Works Manager

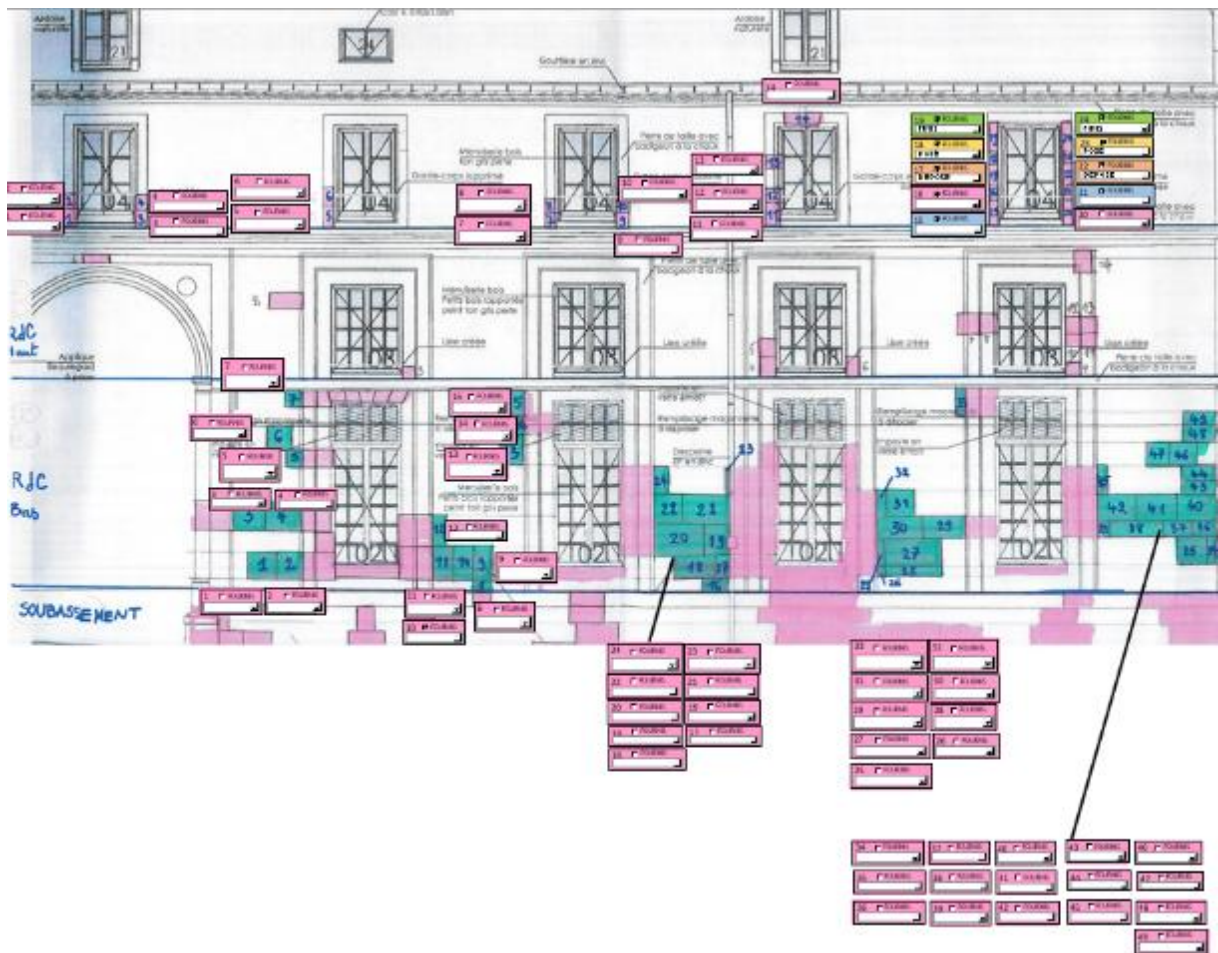


Figure 41- Advancement sheet

This interactive notebook will be used throughout the construction site and will give information concerning the remaining quantities of stone to be laid but also the progress of the stones.

Nous We notice in the upper right part of the previous advancement notebook a series of control boxes of different colours. In order to more quickly identify the condition of the stones from a global point of view on the advancement notebook, I thought it would be interesting to give a specific colour to the control boxes according to the state of the advancement.

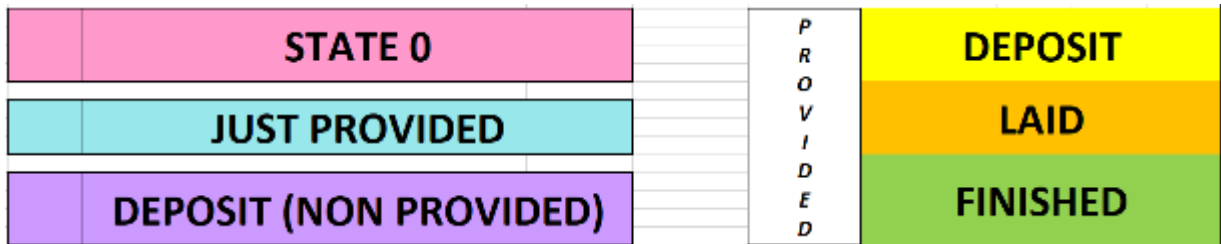


Figure 42- Colours of progress reports

Operations performed automatically.

MARKET												
SOUTH FACADE												
DESIGNATION		DIMENSIONS (cm)				AREA(m ²)	VOLUME (m ³)	STONE	PVD	VOLUME PVD	ADVCMNT	
T1	1	T1 - 1	26,000	15,000	20,000	0,052	0,008	SAINT MAXIMIN BANC 3	o	1,000	Nothing	
T1	2	T1 - 2	20,000	20,000	18,000	0,036	0,007	SAINT MAXIMIN BANC 3	OK	0,007	4,000	Provided
T1	3	T1 - 3	17,000	15,000	34,000	0,058	0,009	SAINT MAXIMIN BANC 3	OK	0,009	4,000	Provided
T1	4	T1 - 4	33,000	20,000	25,000	0,083	0,017	SAINT MAXIMIN BANC 3	OK	0,017	4,000	Provided

Figure 43- Application and verification of progress notebook links

Operations carried out by the Site Manager / Works Manager

SEAL		MARKET								AW								
		BASE	RÉALISÉ	RESTANT		BASE	RÉALISÉ	RESTANT	h/u	BASE	RÉALISÉ	RESTANT		BASE	RÉALISÉ	RESTANT	h/u	
17	JOINING LIME	26,18	25	1,18	m ²	5,24	5,00	0,24	0,20	m ²							0,20	m ²
21	RECOVERY CEMENT JOINTS				m ²				0,20	m ²							0,20	m ²
TOTAL		5,24	5,00	0,24														

PLASTER		MARKET				AW			
		BASE	RÉALISÉ	RESTANT		BASE	RÉALISÉ	RESTANT	
25	PICKING OF PLASTERS	16,00	16		m ²				m ²
34	COATED	16,00	16		m ²				m ²

OTHERS		MARKET				AW			
		BASE	RÉALISÉ	RESTANT		BASE	RÉALISÉ	RESTANT	
46	RE-MESH OF CRACKS	9,37	9,37		ml				
30	MOELLONS LANCES	20,00	20		u				u
13	LIME MORTAR CONSOLIDATION	150,00	150		kg				kg
42	GRAVOIS REMOVAL	2,40	2,4		m ³				m ³
38	COATED PATINA	64,00	64		m ²				m ²

Figure 45- Progress of other tasks

IX.4 « Work » sheet

If we observe the tables presenting the progress of the other tasks, we will see that the stone units are expressed in units, linear meters or square meters unlike the work on cut stone where the units were expressed in cubic meters. To explain this, I take the example of patching and plating tasks. Patching consists in repairing deteriorated elements, which do not need to be replaced. Thus, in order to calculate the "quantity" of patching to be carried out on a facade, it is necessary to calculate the quantities of stones on the studied facade. Take the example of the North Wing North façade. We admit that it has 5 windows on the R + 1. This involves 5 stone window frames, part of which is replaced by new stone and the other patched. In order to calculate (precede by average) the "quantity" of patching to be carried out, we subtract from the totality of the stones present for the frame of the bays the quantity of new stone to be laid. Also, in order to facilitate the operation, the units will be simplified and converted on a sheet called "books".

Operations carried out by the design engineer

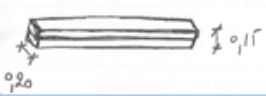

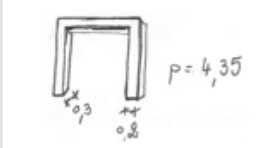

STONES		DIMENSIONS			VOLUMES/AREAS				
STONE ST MAX		WIDTH	THICKNESS	LENGH					
<u>BANNER</u>		0,15	0,20		1,00	ml	↔	0,03	m ³
<u>FULL HANGER</u>		0,35	0,30	2,80	1,00	u	↔	0,29	m ³
<u>WINDOW FRAMING</u>		0,20	0,30	4,35	1,00	u	↔	0,26	m ³
<u>WINDOW FRAMING</u>		0,35	0,30		1,00	ml	↔	0,11	m ³

Figure 46- "work" sheet

IX.5 The score sheet

One would think that from now on - since all the tasks have been created and that their quantities can be modified according to the progress - it only remains to set up a general table making the synthesis of all the edited sheets but it is without counting a sine qua non component that is the real time spent performing these tasks. In order to subsequently compare the time spent on each task, I created a table which assigns a companion per task and per half-day.

The illustration of the score sheet is shown below.

Operations carried out by the Site Manager / Works Manager

			JANUARY					FEBRUARY				MARCH				
			S1	S2	S3	S4	S5	S6	S7	S8	S9	S1	S2	S3	S4	S5
			HOURS					HOURS				HOURS				
FACADE SUD	TASK 1	SUPPLY, REMOVAL AND LAYING OF STONES SAINT MAXIMIN RIGHT	*	*	*	*	*	*	*	*	*	*	*	*	*	*
		DEPOSITION OF DEMOLITION STONES	42													
		INSTALLATION	98													
		FLOW, SIZE AND TRANSPORT OF STONES	110													
	TASK 2	SUPPLY, REMOVAL AND LAYING OF STONES SAINT MAXIMIN COLDNNE	*	*	*	*	*	*	*	*	*	*	*	*	*	*
		DEPOSITION OF DEMOLITION STONES														
		INSTALLATION														
		FLOW, SIZE AND TRANSPORT OF STONES														
	TASK 3	LIME MORTAR CONSOLIDATION	4,5													
	TASK 4	JOINING LIME	40													
	ÂCHE	RECOVERY CEMENT JOINTS														
	TASK 6	PICKING OF PLASTERS	10													
	TASK 7	MOELLONS LANCES	5													
	TASK 8	COATED	29													

Figure 47- Score sheet

IX.6 The « Progress » sheet

The "advancement" sheet is the synthesis of all the previous sheets. It is presented in the form of a summary table linked to all the other tables: to the "location", "tasks" and the "score" sheets. This table contains for the works in the market and additional works 5 columns which take stock of the progress and this for each facade of the works in Compiègne.

- Allocated hours

These are the hours scheduled to complete the defined task. To calculate them, the quantities obtained in the "tracking" sheets are multiplied by the hours defined in the "tasks" sheet.

- Hours worked

These are the hours spent for each task on the site obtained in the "score" sheet.

- Remaining credit

The remaining credit represents the number of hours remaining per task on a given date. These are the hours allocated minus the hours worked.

- Forecast of remaining hours

The remaining hours provisions proceed on the same principle as the remaining credit. However, instead of considering the hours worked, we take into account the hours theoretically worked; that is to say the calculation of the hours allocated according to a given date.

- Forecast Delta

This delta represents the difference between the two previous columns: the remaining credit and the forecast hour remaining. If the remaining hour credits are less than the forecast of remaining hours, the forecast delta will be negative. This means that taking the example of the table below, if the work progresses in the same way, we will spend 4 hours carrying it out compared to what was sold in the market. Conversely, we gain 7 hours on the market for task 6.

Figure 48- additional works

AVANCEMENT		MARKET						
		ALLOCATED HOURS	REMAINING HOURS (quote) Total WF	HOURS DONE	REMAINING CREDIT(h)	ACTUAL DELTA (h)	FORECAST OF REMAINING HOURS (h)	DELTA Prévisionnel (h)
20/01/2020								
SOUTH FACADE								
TASK 1	REMOVE ARCHITECTURAL AND LAYING OF ARCHITECTURAL MARKING	0	*	*	*	*	*	*
°	DISPOSITION OF MARBLE/TILES STUMPS	57	0,2	42	15	14	0	15
°	INSTALLATION	57	0,2	98	-41	-42	2	-43
°	FLOOR, SIZE AND TRANSPORT OF STONES	30	0,1	110	-80	-80	1	-81
TASK 2	SETTING, REMOVAL AND LAYING OF STONES SAINT MAELEN COLOUSE	0	*	*	*	*	*	*
°	DISPOSITION OF MARBLE/TILES STUMPS						NON PLANÉ	
°	INSTALLATION						NON PLANÉ	
°	FLOOR, SIZE AND TRANSPORT OF STONES						NON PLANÉ	
TASK 3	LIME MORTAR CONSOLIDATION	5		5			plus de crédit restant	
TASK 4	JOINING LIME	39	1,8	40	-1	-1	2	-3
TÂCHE 5	REMOVING GARDEN JOINTS						NON PLANÉ	
TASK 6	REMOVING PLANTERS	30		10	20	20	FINISHED	20
TASK 7	WORKING LAMES	5		5			plus de crédit restant	
TASK 8	COUPLER	27		29	-2	-2	FINISHED	-2
TASK 9	COUPLER PATINS	23		5	18	18	FINISHED	18
TASK 10	COUPLER HÉRIQUE	7		5	2	2	FINISHED	2
TASK 11	REPAIRING OF CRACKS	23		20	3	3	FINISHED	3
TOTAL		302	2,3	369	-66	-68	5	-71

MARKET					
	ALLOCATED HOURS	HOURS DONE	REMAINING CREDIT(h)	FORECAST OF REMAINING HOURS (h)	DELTA Prévisionnel (h)
TASK 1	0	*	*	*	*
°	57	42	15	0	15
°	57	98	-41	2	-43
°	30	110	-80	1	-81
TASK 2	0	*	*	*	*
°				NON PLANÉ	
°				NON PLANÉ	
°				NON PLANÉ	
TASK 3	5	5		NO MORE CREDIT	
TASK 4	39	40	-1	2	-3
TÂCHE 5				NON PLANÉ	
TASK 6	30	10	20	FINISHED	20
TASK 7	5	5		NO MORE CREDIT	
TASK 8	27	29	-2	FINISHED	-2
TASK 9	23	5	18	FINISHED	18
TASK 10	7	5	2	FINISHED	2
TASK 11	23	20	3	FINISHED	3
	302	369	-66	5	-71

Figure 49- Progress sheet - market

X Evaluation and final results

X.1 Assessment analysis of results: Expectation 4

X.1.1 Meeting needs

To conclude on the computer tool created, let us recall the main expectations:

- Expectation 1: Simplification of the table produced in a study focusing on the hours credited.
- Expectation 2: Compare actual progress and planned progress.

A simplified final table called “advancement” has been developed in which we find:

- The hours credited meeting expectation 1
- The remaining credits and forecasts of remaining hours meeting expectation 2

We can therefore say that theoretically, the workbook perfectly meets expectations. However, today, it requires intervention upstream by the engineer under study and during construction by the site foreman and the site manager. The objective also is to limit the number of sheets to be completed during the execution phase which will be:

- Debit sheets
- The tracking sheets
- The score sheets

The tool produced makes it possible to detect and anticipate more effectively and quickly whether the allocated hour credits are exceeded, but it is also necessary to ensure the reliability of this.

Finally, the folder created works on the Compiègne site. Indeed, I was able to test the reliability of the tool with the work carried out upstream (the draft of the IT tool). The comparison was made on one of the facades with the additional works and those planned on the market. Similar results appear, but once the Excel workbook is finalized, the time saved to arrive at the same result is significant, especially if the quantity of stone is important. Also, the current computer tool has a huge advantage over manual tracking methods in terms of reliability and time. It would therefore be extremely interesting to put this workbook into practice on other construction sites or similar software. On the other hand, I did not have the opportunity and the time to try the workbook on another site or even on the entire Compiègne site. The reliability of the tool is then still to be proven but before that it is important to improve it and make it adaptable.

X.2 Respect of the phasing and risks

X.2.1 4th step: Development of the informatic tool

Expectations were carried out on schedule, reduced by one week in order to be able to complete the report on time:

- Organize feedback with direct users of the future tools created (site managers and site managers)
- 8 weeks
- Create a simplified tool gathering THMOs (hourly labour time) by activity. This will facilitate the visualization in the works phase of the credits allocated to each task. - 2 weeks
- Set up a tool to make progress comparing the THMO (hourly hours of labour) of the study phase and those of the work phase. - Three weeks
- Ensure the reliability of the tool created and the response to needs - 6 weeks
- The production of practical files and explanatory files of the tools created to optimize price studies.
- 6 weeks

The IT tools put at my disposal to carry out this subject were:

- Microsoft office

The main tool used to accomplish the subject was mainly Excel software.

X.2.2 5th step: Evaluation and final results

- Previsional phasing : **3 weeks**
- Real progress : **1 week**

This 5th stage, from the point of view of monitoring the provisional planning, was the one that least respected it. Indeed, I had initially planned a report for the 20th week of the internship. However, the rendering had to be done 3 weeks earlier. These are the developments of the 4th and 5th stages which therefore had to be readjusted over time.

X.2.3 Final phasing

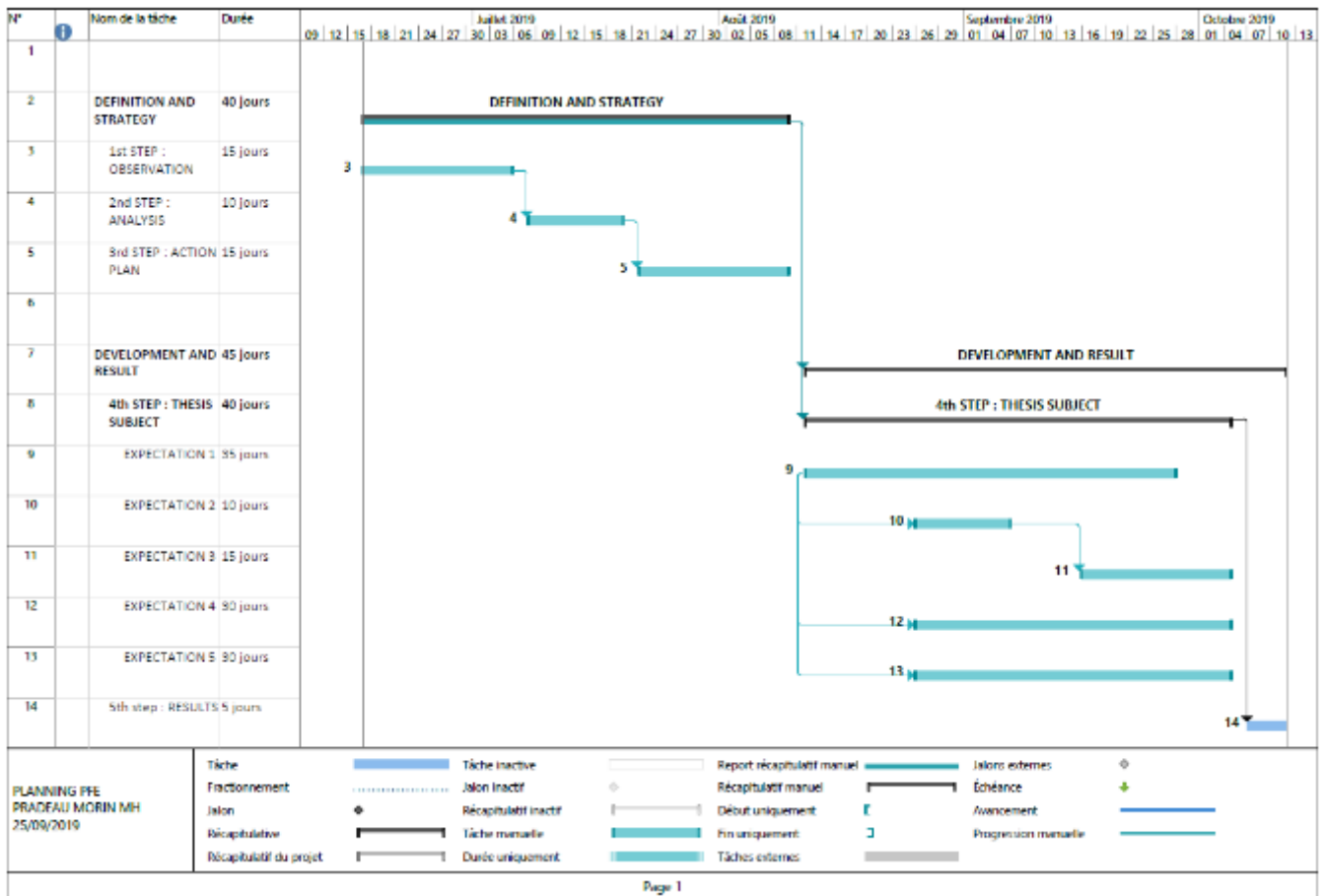


Figure 50- Phasing

X.2.4 Analysis of the results

Risks	Criticality	Result [1-5]
The respected schedule	8	4
Realization of feedback	10	5
Implementation of IT tools	10	4
Knowledge in the fields requested	4	3
Creation of a database	8	4
The tool implemented meets the needs of the company	4	5
The IT tool does not present risks to its use	15	2

Le result varied between 1 and 5

Result	
5	
4	Success
3	Fairly successful
2	Acceptable
1	Not very successful

In general, the development and the results obtained when the computer tool was created have been mastered. Only one point could be problematic: there are risks associated with using the tool. Indeed, I currently have no concrete feedback from the tool made to assert that it poses no risk to its use. It will take me a few more weeks and the optimization of it to finally give me an opinion.

X.3 Critical opinion on the informatic tool

- The IT tool created is based on the Compiègne site. On the one hand, proceeding in this way is interesting since the tool is directly targeted towards a problem and on the other hand, the Compiègne site is a good example of intervention for cut stonework. The problem with the tool is that it is not 100% adaptable. The tool is not autonomous, and this today involves the significant involvement of a design engineer so that it can be operational on another site.
- The study focused on the analysis of cut stonework and the creation of a computer file for cut stonework. However, for other tasks such as drawing or patching (which also take place almost systematically), the tool created is not as suitable (even if it is more than before).
- The filing cabinet allows you to see and monitor the hours spent on site as well as the forecast of hours spent. However, it does not allow to realize the sums committed on the equipment and materials delivered on the site.
- The transfer of stone notebooks to make progress notebooks is not optimal. Indeed, it is currently necessary to place each control box one by one in front of its affiliated stone. This work is (relatively) difficult.

X.4 Implementation of informatic notes : Expectation 5

In order to allow the installed tool to be used in a sustainable way, this involves several things:

- Ensure the functionality of the tool for other future sites
- Improve the tool permanently
- Communicate on the creation of the tool to the managers of the structure and the main stakeholders during meetings.
- Set up information sheets and notes.

On this last point, a manual for using the filing cabinet has been created and will be available to site managers and site managers in order to understand how the filing cabinet works.

The workbook is currently 20 pages long and will evolve with the evolution of the tool. It comes in the following formes :

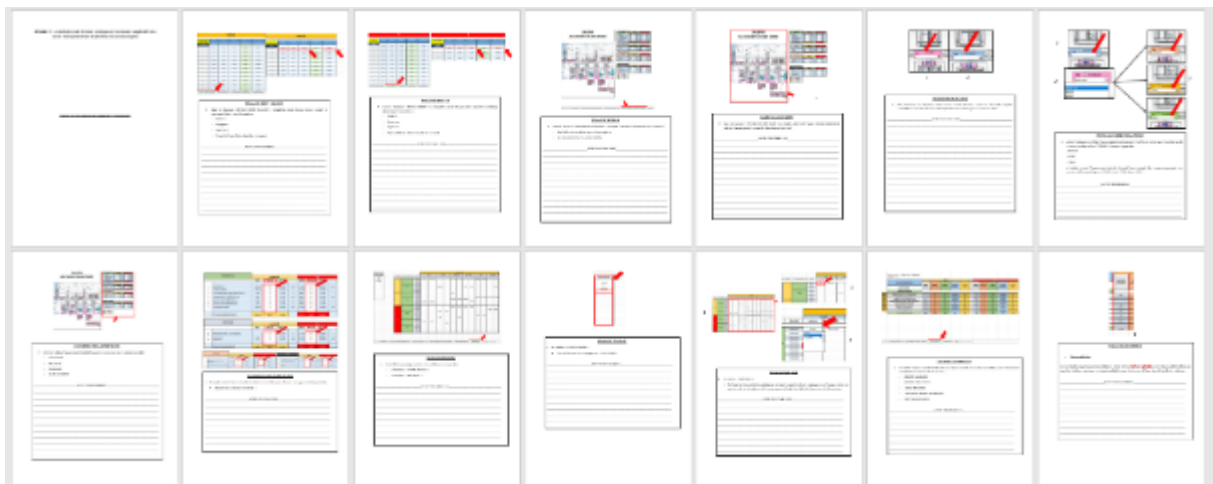


Figure 51- Notices for the informatic tool

The manual pages consist of two parts. An upper part which presents the folder in pictures and a lower part which presents the instructions to follow with a space reserved for personal notes.

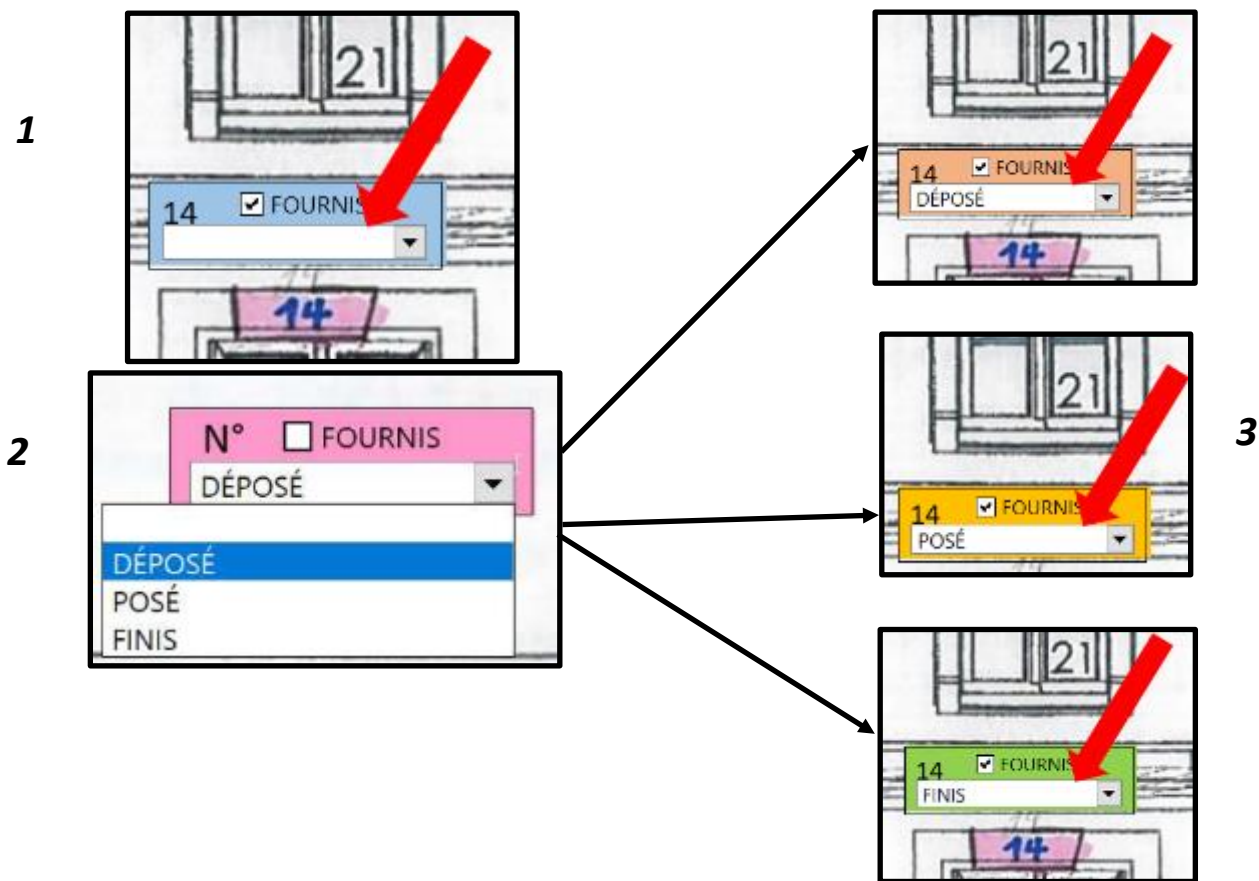


Figure 52- Progress notebook control boxes

Statues of the stone

- To indicate the progress of the stone, click on the cursor under the checkmark called "SUPPLIES".

Three progress reports will appear:

- DEPOSIT
- POSE
- FINISHES

Depending on the progress, the sliders take on a different colour.

Filed: BEIGE. Asked: OCRE. Finishes: GREEN.

PERSONAL NOTES

X.5 Durability of the tool

In order to make the tool durable, it is first necessary to create a tool which meets real needs. Second, the tool must be adapted to its environment and be able to evolve with it. In order to make it durable, I will try to improve the automation of the binder and create a standard binder usable on other sites.

Also, to develop and integrate new features or simply perform maintenance on the workbook, an engineer in study must know the components and be able to intervene at any time on it.

X.6 Probable revision of the tool

Always to enter a concern for sustainability, the tool available is scalable and best suited to current but also future expectations. Therefore, I isolated several axes of improvement of the tool which answer for some to the criticisms of this one:

- Make the tool stand-alone by creating new Macros from VBA coding that automate the functions of the workbook.
- Enrich the task database and make it more adaptable.
- Perform the DPGF directly from this workbook with the enrichment of the database and the creation of sales sheets. The study will no longer be based on an hour credit but also on the sums committed.
- The transfer of notebooks could be done from CAD or CAD software (AutoCAD or REVIT) in order to be able to convert each block of stone defined from software on Excel. The idea is to be able to obtain for each block of stone created, a control box (presented above) affiliated directly in the filing cabinet.

CONCLUSION

During seventeen weeks within Pradeau Mori, I was introduced the profession of studies price engineering for the restoration of historic monuments. I was fortunate to be well supervised and to have been able to work on complex stone projects from the site visit to the submission of tenders.

Also, during these seventeen weeks, I finalized a first version of a computer tool in Excel. This tool responds to specific expectations allowing better monitoring of stone sites. It also responds to a problem defined before the PFE:

"Optimization of price studies in the restoration of historic monuments based on feedback from construction site experiences"

Indeed, this tool optimizes price studies since it automates the measurement of cut stones. Also, if the tool evolves and responds to the probable solutions established in the previous chapter (Disbursed sheet, measurement linked to AutoCAD or REVIT), it could replace certain current working methods. In addition to optimizing price studies, this tool could optimize progress on site. So, if I continue afterwards my work started within the framework of my PFE, I could develop a tool gathering the information of the site from the study phase to the execution phase. This would allow us to follow the works but also to better realize our offers in the study phase.

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