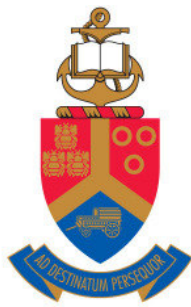


# **Concrete elements: Timber faced formwork systems versus steel faced formwork systems, and which is truly better for the contractor?**

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Submitted in fulfilment of part of the requirements for the  
Degree of Baccalareus Scientiae (Hons) (Construction Management)

In the faculty of Engineering, Built Environment and Information Technology



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Study Leader  
Mr. J.H. Cruywagen  
October 2009

## **Declaration**

I, the undersigned, hereby confirm that the attached treatise is my own work and that any sources are adequately acknowledged in the text and listed in the bibliography.

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Alan Jon van Niekerk

Signature of acceptance and confirmation

## **Abstract**

<b>Title of treatise</b>	Concrete elements: Timber faced formwork systems versus steel faced formwork systems, and which is truly better for the contractor?
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<b>Date</b>	: October 2009

Concrete Construction today remains largely unchanged in basic principle. The largest labour and cost components have long been the formwork used to confine and shape the concrete in its plastic state.

The objective of this treatise is to identify, in theory, whether the modular timber formwork systems being designed and manufactured today, offer realistic and realisable benefits over the modular steel formwork systems that have been used for many decades in the South African construction industry.

Research focuses on three examples of each system and is restricted to vertical forms, i.e. those used for columns, walls, beam sides and *etc.* It looks at the physical ergonomics, the quality of concrete finish produced, the durability of the formwork and the associated components and lastly compares the value in terms of rental and purchase prices per square meter.

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## **Chapter 1**

### **1) Introducing the research**

#### **1.1) Background**

Traditionally, all formwork was fabricated on site. Sheathing of plywood or other timber boards were supported by vertical and horizontal timber bearers known as soldiers and walers respectively. All timber was cut to size on site and assembled by skilled carpenters into what is commonly known as formwork.

Good care during formwork striking could allow much of the timber to be re-used for further concrete pours, but in reality it was seldom possible to strip the forms without damaging the majority of the timber. Furthermore the unique nature of construction made it unlikely that the cut timbers were of a suitable size for further form building. For these reasons, it is obvious that the consumption and waste of timber on construction sites was high.

Increased time constraints and shrinking profit margins for building contractors made it essential that new methods of concrete forming were developed.

Important requirements were easy site assembly and re-usability so as to maximize contractor profit.

The result was the development of factory manufactured modular formwork panels, which could be joined together on site to create the size and shape of the concrete element desired.

Over the years, the idea has remained the same, but it is a fiercely competitive market for the manufacturer who can provide the most efficient and practical product using various materials and innovative ideas.

The debate between wooden or steel formwork systems for concrete elements is one that has raged on construction sites since the advent of these form panels.

Typically, a construction site will show a polar distribution between younger engineers, foremen and site management who prefer the more modern timber faced form panels and their older, more experienced, yet stubborn, colleagues who could spend the entire day telling you why the original steel faced form panels were, still are, and always will be the best.

Construction in the 21<sup>st</sup> century makes extensive use of concrete elements both structurally and aesthetically. It is therefore essential for construction contractors to use formwork systems which offer them the best value for their money, in order that they may gain competitive advantage over rival companies.

## **1.2) Stating the main problem**

**Concrete elements: Timber faced formwork systems versus steel faced formwork systems, and which is truly better for the contractor?**

This research will compare the two methods of formwork systems for vertical concrete elements and attempt to prove that modern timber systems are better than the outdated steel systems.

## **1.3) Stating the sub-problems**

### **1.3.1) Sub problem 1**

- **Which system is ergonomically superior?**

Ergonomics defined:

*The applied science of equipment design, as for the workplace, intended to maximize productivity by reducing operator fatigue and discomfort.*

<http://www.thefreedictionary.com/ergonomics> Access 12 March 2009)

This chapter will compare the two systems based on weight and standard panel sizes, which directly influences the ease of positioning and manipulating the system panels, as well as comparing the assembly components which will directly affect the ease and speed of assembling the system.



### **1.3.2) Sub problem 2**

- **Which system ensures a better quality of finish to the concrete element?**

This will identify which system produces the most uniform, straight, smooth, flat and attractive concrete surface.

### **1.3.3) Sub problem 3**

- **Which system is the most durable and longer lasting?**

This will identify which system is the most resilient and resistant to abuse and damage by handling, concreting and inclement weather.

### **1.3.4) Sub problem 4**

- **Which system will provide the best value for money to the contractor.**

This will identify which system provides the best value for money for the thrifty contractor.

## **1.4) Stating the hypotheses**

### **1.4.1) Hypothesis for sub-problem 1**

The timber faced forms will prove to be the better system ergonomically due to superior design quality of the assembly components.

### **1.4.2) Hypothesis for sub-problem 2**

New steel always provides the best possible concrete finish, but it deteriorates quickly. The easily refurbished and replaceable faces of the timber systems should impart a better finish quality for longer.

### **1.4.3) Hypothesis for sub-problem 3**

The surfaces of timber faced forms are very susceptible to damage through physical battering and weather but are more easily repaired than the steel forms which dent and deform. This means the timber system should prove less durable, but longer lasting.

### **1.4.4) Hypothesis for sub-problem 4**

The longer life cycle obtained from timber faced forms, as well as the cost saving which results from reduced erecting and striking times will make them the more cost effective option for the contractor over time.

## 1.5) Delimitations

- **Systems, not products.**

This research will be based on the comparison of two methods of formwork for concrete elements. It will not be focused on the rivalry between two specific opposing systems, nor that between two different manufacturers. The purpose is not to prove that one *product* is superior to another, but rather to determine which *systems*, steel faced or timber faced, are superior.

- **Vertical elements, not horizontal.**

This research is only going to involve vertical concrete elements, such as concrete walls, columns, sides of beams and stopped-ends to surface beds and suspended slabs. Formwork to horizontal concrete elements like beam and slab soffits will not be included in this treatise.

- **Straight, not round.**

This research is limited to straight concrete elements. Round, curved, or any concrete elements with a radius are excluded from this treatise.

- **Design strength and bearing capacity of the systems.**

This research will look at many different concrete forming systems, all of which are locally approved and used regularly throughout the country. All the systems are sufficiently strong and fit for purpose if used correctly according to the designers' specifications and taking cognizance of the loads specific to the job at hand.

- **Locally manufactured or local agency only.**

As there are many different concrete forming systems available worldwide, far too many to mention, this research is limited only to those products which are common and freely available within South Africa.

This research will not include international products which are available for private import into South Africa, but only those with dedicated agencies in South Africa.

## 1.6) Definition of terms

- **Formwork system:** A concrete formwork product in its entirety, including the panels, as well as the assembly components. Essentially, all the equipment that is required to assemble and use the formwork.
- **Assembly components:** All the additional equipment required to connect and align the form panels to one another, as well as tie the opposing form faces and prevent movement or deformation of the form. This may include any or all of the following; Alignment couplers, wedge clamps, alignment bars, tie rods and nuts, stays and braces, props, etc
- **Modular timber formwork system:** Formwork panels with frames constructed of timber, steel or both, and sheathing comprising a timber board. This timber face is coated with a phenolic resin to impart a flat smooth surface to the concrete and avoid imprinting the grain of the wood on the finished element. This also includes all the necessary assembly components. Henceforth referred to as MTFS
- **Modular Steel formwork system:** Form panels that are constructed entirely of steel, including the frame and surfacing. Includes all the necessary assembly components. Henceforth referred to as MSFS
- **Shutter:** A common colloquial South African reference to formwork of all types, irrespective of the design, size, material of manufacture, Etc.
- **Stop ends:** Either a temporary or permanent vertical form, used to confine wet concrete being placed as slabs or surface beds. Stopped ends are used to form construction joints, expansion joints, or simply to define the perimeter of the slab or surface bed.

- **Shutter oil:** Another colloquial expression referring to concrete form release agents.

## 1.7) Importance of the study

Concrete is still the single largest construction material being used throughout the world, and for this reason, it is essential for contractors to make informed decisions regarding the choice of forming system they will use, so as to maximize shutter turnover and shutter lifespan, and therefore maximize project profits.

This research aims to identify the superior of two types of concrete forming systems and also provide a body of information that will provide the reader with the facts needed to make an informed decision regarding which forming system is better, based on South African systems, used under South African conditions.

The intention is also to stimulate and encourage renewed interest in this debate, so that more research is done and perhaps better systems may be developed, which is to the greater benefit of the built environment community.

## 1.8) Research Methodology

- Textbooks, academic articles, reports, internet articles and product catalogues will be used to assess the existing research on the subjects of timber and steel formwork and lay down the framework and basic theory behind each method.
- Physical observation on site in order to identify the reality of using the systems
- Personal interviews will be conducted with shutterhands, labour, foremen and site engineers in order to determine the opinion of the people on site, who use these systems on a daily basis. Their perspective differs from that of site management and as such it is critical to a realistic study that these opinions are considered.
- Personal interviews with site agents, contracts managers, quantity surveyors and company directors. The perspective of management is also important to identify the financial and time related aspects of the systems.

- Personal interviews with designers or agents of various formwork companies.
- Furthermore, surveys of different sites, projects, and contractors will also be used to assemble a large body of personal experiences and determine the greater opinion that contractors have of the two systems.

## **Chapter 2**

### **2) Ergonomics and design**

#### **2.1) Introduction to the chapter**

The purpose of this chapter is to compare the design and construction of the various modular forming systems in an impartial and unbiased way.

This should serve to identify all potential weaknesses of the systems and allow the reader to form a fair personal opinion of the systems.

The following aspects of the respective systems will be described and then compared, based on product data supplied by the manufacturers.

All the information supplied by manufacturers is held as fact.

- 1) Individual panel weights, sizes and areas so as to determine the weight per m<sup>2</sup>.  
This will allow conclusions to be formed as to which system is lighter and therefore easier to carry and manipulate.
- 2) The physical design and construction of the panels in terms of materials and dimensions
- 3) The assembly of the panels and how they come together to provide a form for the casting of concrete elements.

## 2.2) Body of the chapter

### 2.2.1) Panel weight

Panel	Panel size	Panel weight	Panel area	Approximate weight per m <sup>2</sup> of panel
Formscaff Economy form	1000 x 500	25.05	0.5	50.10
	1500 x 500	36.60	0.75	48.80
	2000 x 500	48.13	1.0	48.13
	2500 x 500	59.68	1.25	47.74
	3000 x 500	71.22	1.5	47.48
<b>Average weight of panels in Kg / m<sup>2</sup>.</b>				<b>48.45</b>
Uni-span economy panel	900 x 500	22.2	0.45	49.33
	1500 x 500	35.0	0.75	46.66
	2100 x 500	48.7	1.05	46.38
	2400 x 500	56.5	1.2	47.08
	3000 x 500	70.2	1.5	46.80
<b>Average weight of panels in Kg / m<sup>2</sup>.</b>				<b>47.25</b>
Wiehahn Economy form system	1200 x 600	32.9	0.72	45.69
	1500 x 600	39.9	0.9	44.33
	1800 x 600	48.2	1.08	44.62
	2400 x 600	63.5	1.44	44.09
	3000 x 600	78.8	1.8	43.77
<b>Average weight of panels in Kg / m<sup>2</sup>.</b>				<b>44.5</b>
<b>Average weight per m<sup>2</sup> of the 3 systems.</b>				<b>46.73</b>

**Table 1.** Comparison of steel formwork panel weight.

*Source: Author*

- **Discussion of table.**

A sample of five different panel sizes was chosen from each manufacturer of steel form panels. All three manufacturers produce their panels in differing modular sizes according to their design and their target markets, making use of increments of 100, 150, 300, 500, 1000mm among others.

The data used in this comparison is by no means comprehensive as many different sizes of panels are available, including panels custom-made to practically any size required by contractors.

For want of space, only 5 panel sizes were included from each manufacturer, this in spite of the fact that each manufacturer lists in excess of 40 different combinations of sizes available, as well as custom made panels to the clients' requirements.

This selection of panels attempts to represent this broad range as accurately as possible with a small sample.

According to Dawson (1979) the standard panel sizes are the 500, 1000, 1500, 2000 and 3000mm sizes. Formscaff panels were selected first as their standard sizes most closely represented those mentioned by Dawson. Thereafter the Uni-span and Wiehahn panels were selected to be the same or as near as possible to the Formscaff panels, in order to improve the comparability of the results.

The sample does therefore serve accurately to represent the products as the weight of a panel is reliant on the area of the panel. This is because the area of the panel will determine the length of the perimeter framework, the area of the facing, and the number and spacing of the built-in stiffeners.

Table 1 shows an inverse relationship between panel area and weight per m<sup>2</sup>. This means that the relative weight per m<sup>2</sup> of form panel decreases as the panel sizes increase. This is due to the fact that a smaller panel still has to have 4 perimeters made of flat steel bar, and the built in steel angle stiffeners. As the panels increase in size, the quantity of the perimeter section and integral stiffeners decreases in proportion to the area of the panel. This has the result of larger panels being proportionately lighter than smaller ones.

It is seen in the results that the Wiehahn panels are the lightest at 44.5 kg/m<sup>2</sup>, with the Uni-span panels following at 47.26 kg, and the Formscaff panels are the heaviest at 48.45 kg/m<sup>2</sup>. The average weight is shown to be 46.73kg/m<sup>2</sup>, meaning that the Wiehahn panels are lighter than the average, whilst the Uni-span and Formscaff panels both exceed the average weight.

According to Jacobs (8 April 2009), Formscuff are not ashamed of having the heaviest product in this category, as the steel angles and flat bars they use for their framework and stiffeners are thicker than those used by other manufacturers. This provides a stronger, stiffer panel at the cost of a slight weight increase.

Panel	Panel size	Panel weight	Panel area	Approximate weight per m2 of panel
Formscuff Tifa-lite	1200 x 300	18.8	0.36	52.22
	1200 x 600	27.0	0.72	37.50
	1500 x 300	22.8	0.45	50.66
	1500 x 600	33.5	0.9	37.66
	2700 x 300	41.7	0.81	51.48
	2700 x 600	58.3	1.62	35.98
<b>Average weight of panels in Kg / m2</b>				<b>44.25</b>
Doka Frami 300	1500 x 300	23.0	0.45	51.10
	1500 x 600	35.0	0.9	38.80
	1500 x 900	43.3	1.35	32.07
	3000 x 300	43.5	0.9	48.33
	3000x 600	64.2	1.8	35.66
	3000 x 900	84.7	2.7	31.37
<b>Average weight of panels in Kg / m2</b>				<b>39.55</b>
Peri Domino	750 x 500	18.3	0.38	48.15
	750 x 750	26.0	0.56	46.42
	1250 x 500	28.2	0.63	44.76
	1250 x 750	37.80	0.94	40.21
	2500 x 500	53.50	1.25	42.80
	2500 x 750	70.1	1.88	37.28
<b>Average weight of panels in Kg / m2</b>				<b>43.26</b>
<b>Average weight per m2 of the 3 systems.</b>				<b>42.35</b>

**Table 2.** Comparison of timber formwork panel weight.

Source: Author

- **Discussion of table**

The sample selection for the MTFs was done on the same basis, and for the same reasons, as that of the MSFS

The table for modular timber formwork systems shows similar results to the table of modular steel formwork systems.

Once again smaller form panels are heavier per m2 than larger panels.



This trend is very prominent on the Doka Frami 300 panels, where a 300mm width is found to weigh on average 12.48 kg more per m<sup>2</sup> than a 600mm width panel, which in turn tips the scales at an average of 5.51 kg more per m<sup>2</sup> than a 900 mm width panel. Formscraft's Tifa-Lite panels also show substantial weight reduction as the panel sizes increase, with an average weight drop of 14.40 kg per m<sup>2</sup> between the 300mm and 600mm width panels respectively.

The Peri Domino system shows the same trend, but to a much lesser extent, with the 750mm width panels weighing in on average 3.93 kg less per m<sup>2</sup> than the 500mm panels.

This trend is the result of the heavy framework and stiffeners that have to support the timber sheathing which confines the plastic concrete.

- **Comparison of results.**

The results produced by the two tables show a noticeable difference when comparing the weight of the two systems. The MTFs produced an average of weight 42.35kg/m<sup>2</sup> between the three products, whilst the MSFS weighed in at on average, 4.38 kg/m<sup>2</sup> lighter than the MSFS at 46.73 kg/m<sup>2</sup>.

The weight reduction effect was found to be far greater in the case of the MTFs than in MSFS. This is due to the fact that the MTFs start out heavier, owing to a more substantial metal framework needed to provide strength and stiffness to the flexible composite timber sheathing, and to allow for the proper functioning of the connecting systems. As the panel sizes increase, the timber systems become considerably lighter than the steel systems. This is because of the weight saved by using composite timber sheathings instead of steel plate.

The physics fact-book gives the density of cold drawn mild steel as:  
7.83 grams/cm<sup>3</sup>. <http://hypertextbook.com> (Access 10 April 2009)

For one square meter of 3mm thick steel, as used to face the steel systems, the following applies:

$$\begin{aligned}(100\text{cm} \times 100\text{cm} \times 0.3\text{cm}) \times 7.83\text{g/cm}^3 &= 23490 \text{ grams} \\ \rightarrow 23490 \text{ grams} \div 1000 & \\ &= \underline{\underline{23.49 \text{ kg/ m}^3}}\end{aligned}$$

Compare this with the approximated weight per m<sup>2</sup> of 15mm plywood, coated both sides with phenolic resin, as used in the three timber faced systems, given as 10.20 kg/ m<sup>2</sup> by Peri plywood, (2007). The steel facing is more than double the weight of the timber facing, per m<sup>2</sup>, and it is apparent why the MTFs offers substantial savings in weight despite having a bulkier framework.

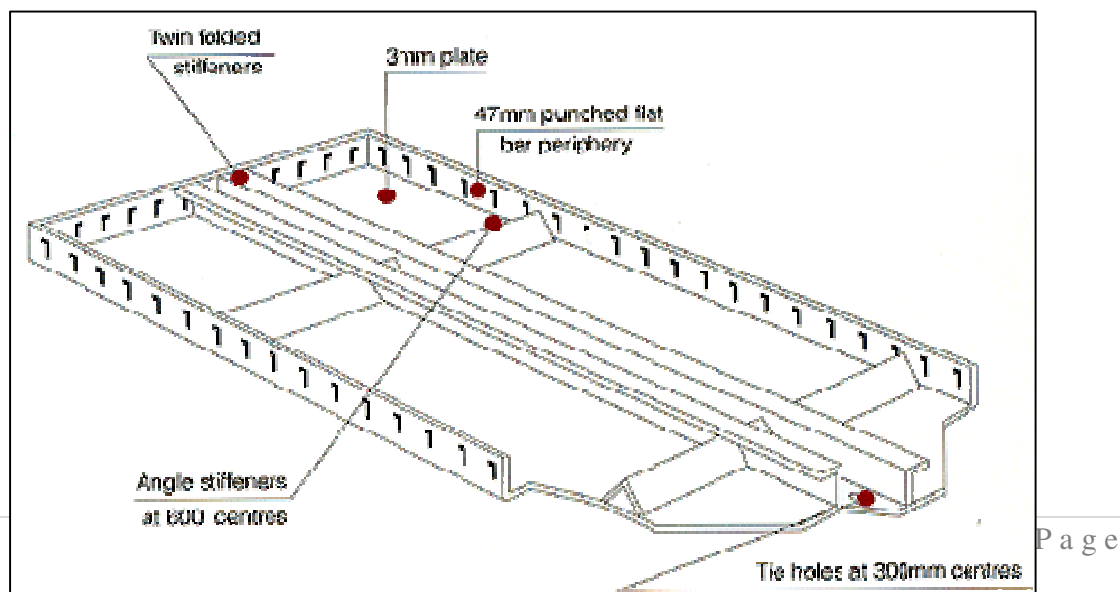
- **Application of results**

It has been shown that the timber system panels are lighter than the steel system panels by 4.38 kg/m<sup>2</sup>, and it is obvious that the result will be reduced strain and fatigue on the employees who carry and lift these panels into position during their working shift. By minimizing the weight of the panels, the contractor will reduce the strain and fatigue experienced by his labour force, and in so doing, the possibility of injury to workers is substantially reduced. This should lead to an increase in productivity, a decrease in downtime and a decrease in compensation insurance fees paid. All of which is likely to benefit the contractors profit margin.

### 2.2.2) Panel design and construction, and the effects on handling.

- **Steel panels design**

The MSFS are all of very similar construction. Essentially, they comprise a rectangular frame of 50 x 3 mm flat steel section, with a 3mm thick steel facing. The framework also contains steel angle sections as integral stiffeners, which run behind the facing across the width, and in larger panels, across the length of the panel. The perimeter framework has rectangular slots punched at regular intervals which allow for the alignment and connection of panels using the wedge sets.



**Figure 1.** Typical section of the economy panel.

Source: [www.unispan.co.za](http://www.unispan.co.za) Access 03/04/2009

The sharp edges and corners of the narrow steel sections and angles make for difficult and uncomfortable carrying and handling of the panels. Even with gloved hands, these edges are prone to cause injury. The narrow, 50 mm width of the frame sections means the panels are invariably carried on the foremost portion of the fingers, the fingertips and the first joint, which leads to unnecessary discomfort and strain on the workers most valuable tools, their hands.

A personal survey, by the author, of 30 workers, comprising shutterhands and labour, who have worked with these panels regularly, found that they all complained about the difficulty of carrying the panels and of lifting them into position.

According to shutter hand Petrus Ndlazi, (05/03/2009),

“We normally move these panels with a pallet trolley or the crane. When we must lift them, we use a piece of wire or rope through a hole. Otherwise they are too difficult to lift because our fingers are sore.”

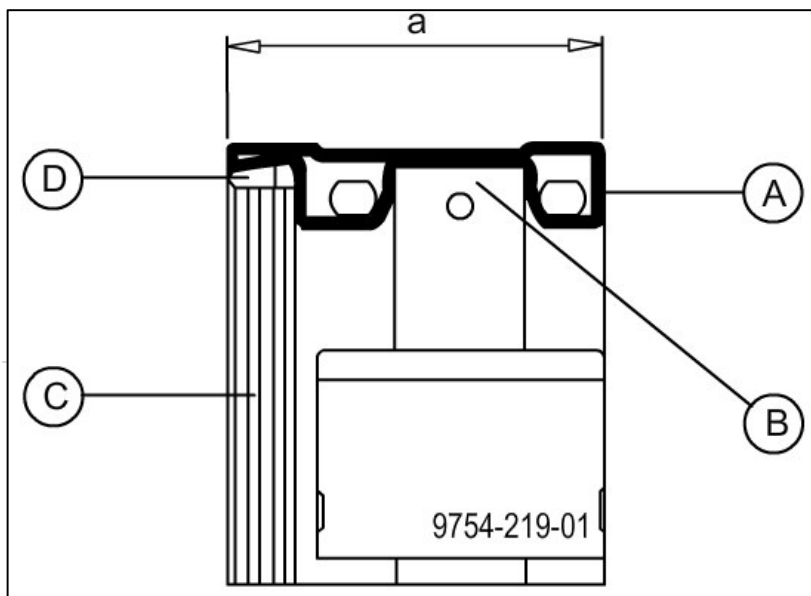
### • Timber panel design

All three timber systems are constructed of hollow steel profiles. The exact shape and dimensions of the profile vary slightly from system to system, but these discrepancies are not of consequence to this text.

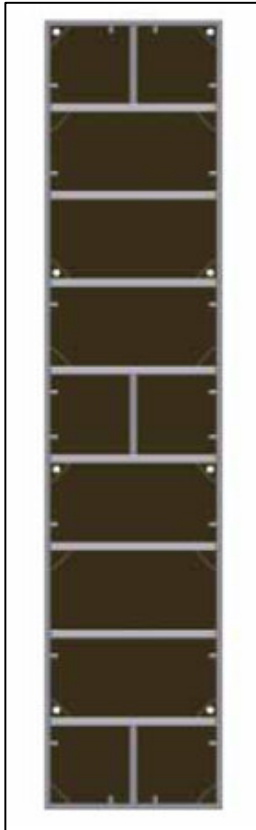
This profile is used for the framework and for the integral stiffeners, which, much like the steel systems, run behind the facing across the width of the panel.

The thickness of the panels as per a, in image 2 are as follows:

- Doka Frami 300: 92mm
- Peri Domino: 117mm
- Formscraft Tifa-Lite: 115mm



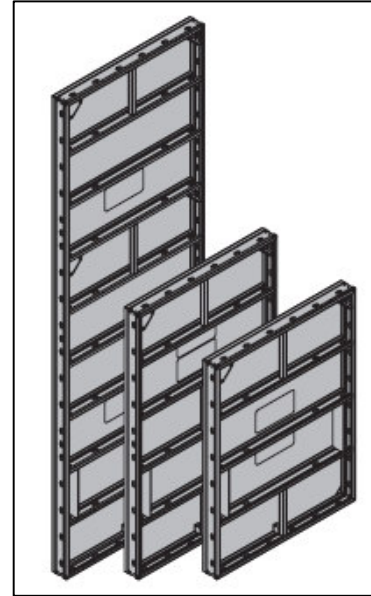
**Figure 2.**  
Typical section of hollow profile used in MFTS.  
A) Hollow profile  
B) Continuous slot for connecting clamps  
C) Timber sheathing  
D) Silicone sealing strip.  
*Source: Doka formwork.*



**Figure 3.** Formscraft  
Tifa-lite  
*Source: Formscraft*



**Figure 4.**  
Peri Domino.  
*Source: Peri*



**Figure 5.**  
Doka Frami 300.  
*Source: Doka*

The above figures show that the construction of all three MTFS is very similar in nature. Evident in all three are the integral stiffeners that obviate the need for walers. All three timber systems have built in handles, to make carrying easier. These are the short steel sections that are seen in the images to run parallel to the longer face of the panels. They are located at the ends of all three panels, and the Tifa-lite and Frami-300 also have carry handles in the center.

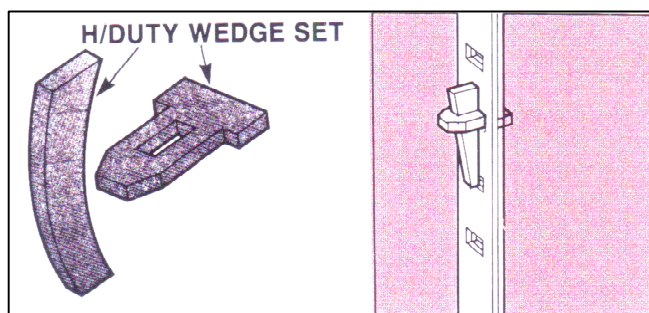
These carry handles allow for two, or even three men to carry the panels beside themselves as they walk. It is found on site that the workers much prefer the built in handles of the timber systems. Even when the handles provided are not used for whatever reason, the wider frame of the hollow steel sections, as mentioned earlier, would make for much more comfortable carrying, as the full weight of the panels will be

borne by the workers hands and not by the fingertips as was found to be the case with steel formwork panels.

### 2.2.3) Assembly

- **Steel system assembly**

All three steel forming systems operate in much the same way. Steel tee and wedge sets are used to connect the panels together through the rectangular punched slots in the periphery. The wedge sets also serve to partially align the faces and edges of the panels.



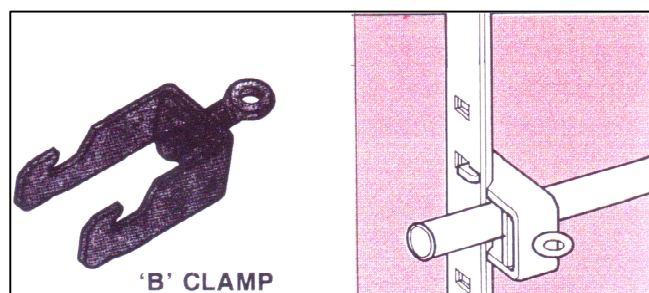
**Figure 6.** Tee and wedge set, and how they connect adjacent panels through the punched slots.

*Source: Formscuff*

The wedge sets alone, however, are unable to provide significant strength and rigidity to the joint. For this reason walers or soldiers will be needed to perpendicularly cross the joint line between the panels.

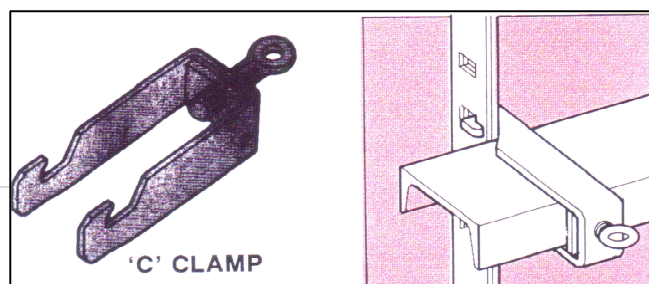
From the Formscuff product catalogue (Date unknown)

Stiffeners built into the panel, therefore only two scaffold tube walers are required for alignment.



**Figure 7.** B-clamp used to fasten 40mm scaffold tube to form panels, as a soldier or waler for rigidity.

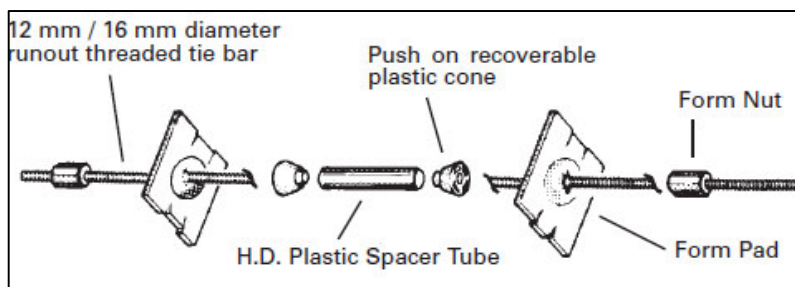
*Source: Formscuff*



**Figure 8.** C-clamp used to fasten channel iron to form panels as a soldier or waler for heavy duty application.

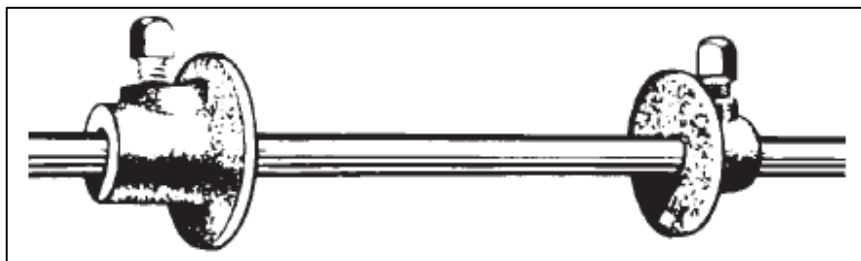
*Source: Formscuff*

The typical practice is to use scaffold tube, or even scaffolding ledgers as walers and soldiers, but in the case of heavy duty application, such as extremely tall or thick forms, or where the panels are used as a gang form, channel iron should be used to ensure the strength and uniformity of the form. It is essential that all vertical formwork has a tie system to tie the opposing faces in position, to prevent them from distorting or “kicking”.



**Figure 9.**  
Threaded rod, nut and backing plate tie system.  
*Source: Wiehahn*

Two tie systems are available for the MSFS. With the threaded rod system, the ties are passed through a sacrificial plastic sleeve and then through the form. The backing plates are added to distribute the force, and the nuts are securely tightened using a large spanner. Afterwards, the tie can be removed and the plastic sleeve will remain in the concrete.



**Figure 10.**  
Rebar and ferrule tie system.  
*Source: Wiehahn*

With the rebar tie system, 8 or 10mm rebar is cut to appropriate lengths and passed through the form. The ferrule heads, or dollies, are jacked tight using a ferrule jack and then the retaining nut is tightened. Typically, the Rebar system is such that the tie remains in the concrete and the ends must be cut off and the concrete patched. It is noted that there is nothing stopping the user from using the same plastic sleeves as above to allow the rebar tie to be removed after use.

- **Timber system assembly**

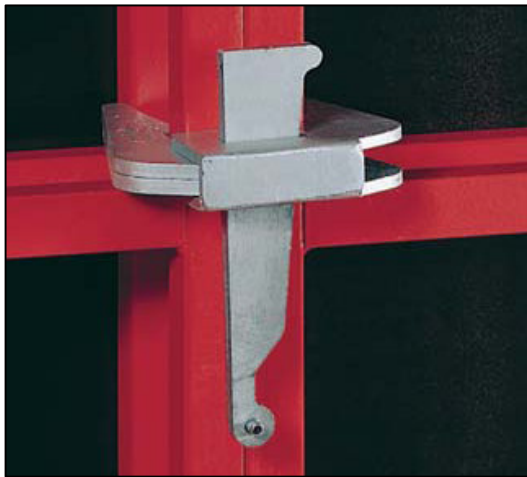
The three timber forming systems make use of similar, yet unique and product specific assembly components.

All three use some a form of self aligning clamp. Two categories of self aligning clamps are applicable, namely those that are suitable for standard panel joints only and those that are adjustable to accommodate a range of patch sizes.

The clamps are placed over the joint, and the wedge or toothed pin is driven hard with a hammer to tighten the clamps. The clamps fasten securely and the panels are accurately aligned, providing a joint that is rigid enough to obviate the need for walers.

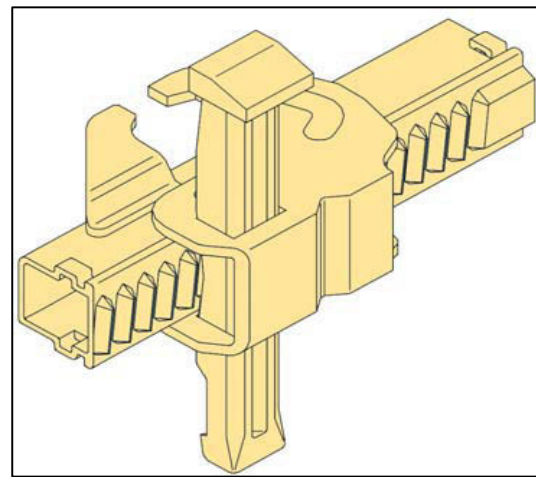
**Figure 11.** Domino DKS coupler, only for standard joints, does not accommodate patches.

*Source: Peri*



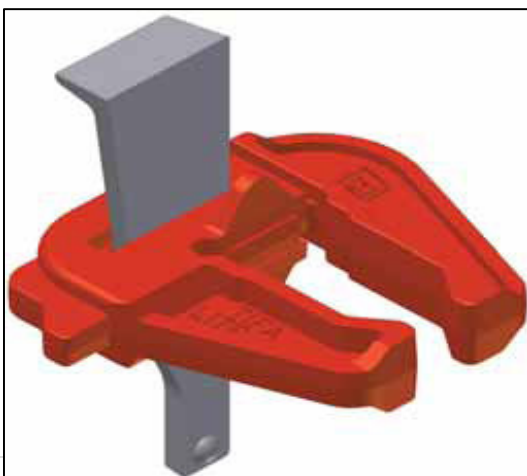
**Figure 12.** Domino DRS coupler for use on standard joints or joints with patches up to 120mm.

*Source: Peri Formwork*



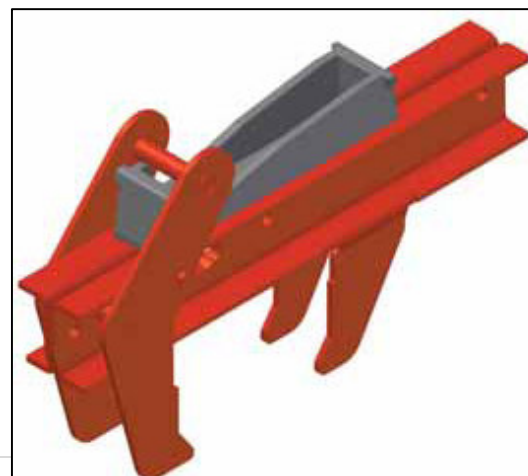
**Figure 13.** Tifa-Lite Crab clamp for standard joints only, does not accommodate patches.

*Source: Formscraft*

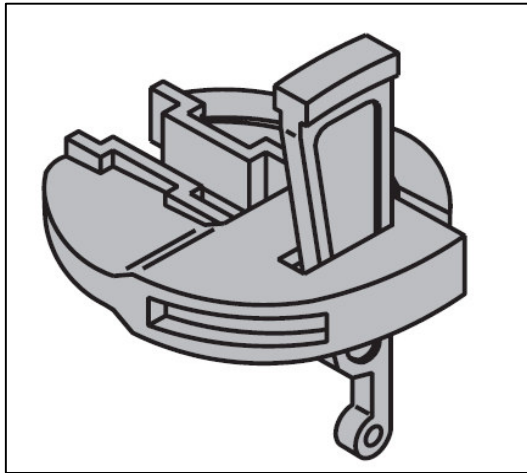


**Figure 14.** Tifa-Lite adjustable clamp for standard joints and joints with patches up to 120mm

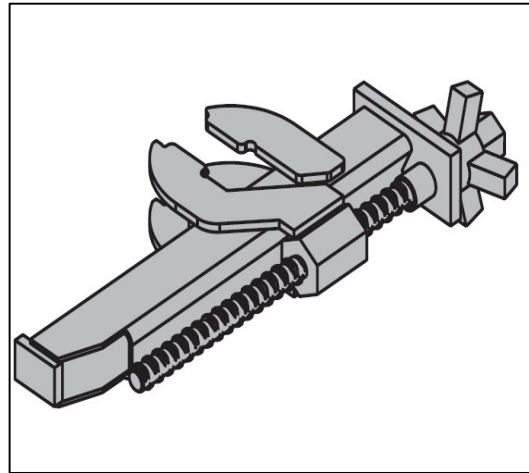
*Source: Formscraft*



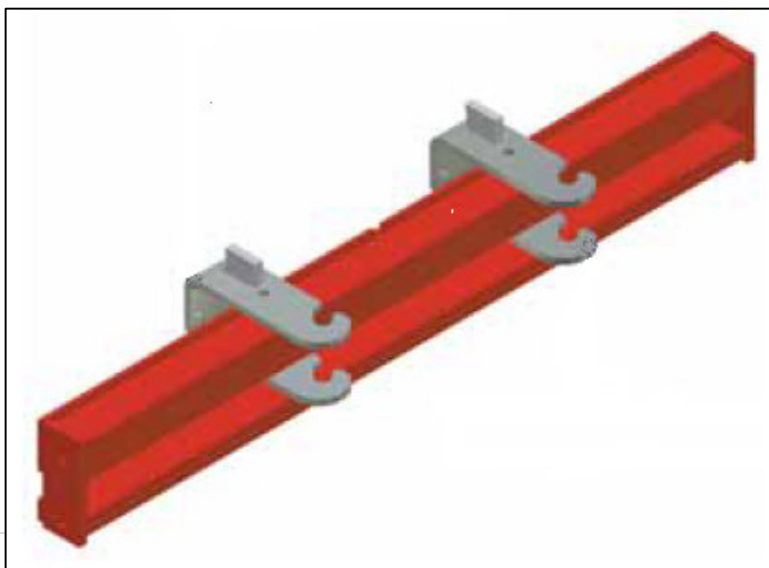
**Figure 15.** Frami clamp for standard joints only. Does not accommodate patches.  
*Source: Doka*



**Figure 16.** Frami adjustable clamp, for standard joints and joints with patches up to 150mm.  
*Source: Doka*



All three MTFs have made redundant the need for walers and soldiers by designing very rigid bearers into the frame, and by using very powerful alignment clamps to connect the joints. They provide for compensation walers to be used at stopends and where patches are larger than what can be accommodated by the adjustable clamps. These simply comprise a hollow steel section that securely attaches to the form panels either side of the patch and provides a backing for the in-situ timber in-fills and patches

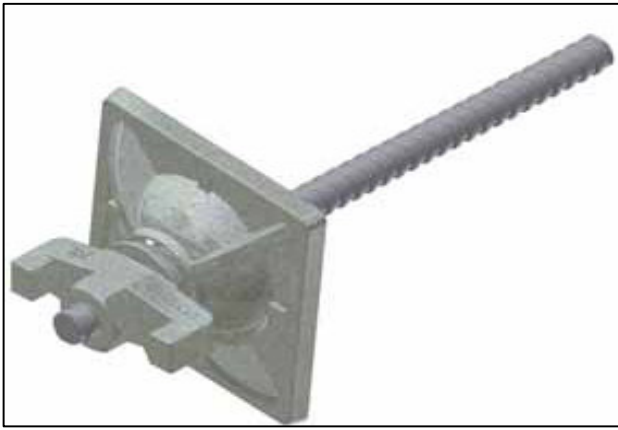


**Figure 17.** Compensation waler to support timber in-fills and stop-ends.  
*Source: Formscalf.*



Tie systems for MTFs are not much more advanced than those described for MSFS, and in fact, all tie systems are compatible with any other form system.

The greatest advantage of MTFs tie systems is the inclusion of a captive backing plate, meaning that the backing plate is permanently affixed to the fastening nut so as to prevent loss of the components. A further development is the wings on the fastening nut which allow for hand tightening without the use of expensive spanners which are prone to damage, loss and theft.



**Figure 18**  
Dywidag  
threaded tie  
rod, with nut  
and captive  
backing plate.  
*Source:*  
*Formscaff*

### **2.3) Summary**

This chapter shows a consideration of the physical design aspects of the MTFs and the MSFS, with particular attention to the ergonomics of the systems.

First the systems were compared in terms of the average weight per m<sup>2</sup> of form to determine which was the lightest and easiest to manipulate.

Thereafter the actual design and construction of the panels from the two systems were compared so as to establish which was the least harmful to the workers who work with formwork on a daily basis. Lastly, the text approached the assembly of the systems into forms from the perspective of the workings of the assembly components required to build a complete shutter for the confinement of plastic concrete.

### **2.4) In conclusion**

In conclusion, it is apparent to the construction professional that the MTFS has proven to be ergonomically superior, and better designed than the MSFS. The design of the MTFS has benefited from the use of modern computer design software to identify all potential weaknesses before the systems were ever manufactured, and also from the availability of modern materials such as the composite timber facings, which proved to provide substantial weight savings.

## **2.5) Testing the hypothesis**

To restate the hypothesis:

The Modular timber formwork systems will prove to be better ergonomically due to superior design of the form panels and assembly components. This chapter has well proven that the MTFS is in fact better designed with regard to providing a worker friendly, quick and easy to assemble forming system.

## **Chapter 3**

### **3) Which system ensures a better quality of finish to the concrete element?**

#### **3.1) Introduction to the chapter**

Concrete is a commonly used structural construction material because of its high compressive strength properties and its resistance to the elements.

It is also an extremely popular outlet for the expression of architectural creativity. Without the help of concrete this creativity, which has resulted in some of the most inconceivable design ideas, aided by modern techniques and computer designs, may never have been realised.

It is good practice for the contractor to ensure that the formwork used provides as high a quality finish as is possible within the time and cost constraints allowed by the client. This is critically important with fair-faced, off-shutter concrete where no further finishing is applied, but is also significant to purely structural concrete.

With fair-faced concrete it is obvious that the concrete surface must be dimensionally accurate and defect free with a uniform and smooth appearance, so that there is little or no finishing required disguising an unsightly surface.

With regard to purely structural concrete which will receive some form of finish such as cladding, plaster, or otherwise, a poor quality formed concrete surface can cause unnecessary difficulties in the finishing of the building or structure as the concrete elements may be misaligned, out of square, or of the incorrect dimensions and proportions.

The type and quality of finish attained when casting concrete elements into forms depends on numerous factors such as:

- Cement Types
- Concrete Mix Design
- Formwork
- Concrete Pressure on Formwork
- Form Release Agents
- Workmanship
- Formwork striking times

<http://www.ecocem.ie> (Access 5 may 2009)

As this text is centred on formwork, the other extrinsic factors will be ignored, and the focus of this chapter is on the effect that formwork has on the appearance of the formed concrete surface. The purpose therefore, is to identify whether timber faced forms or steel faced forms will produce the most uniform, straight, smooth, flat and attractive, useable concrete surfaces.

## **3.2) Body of the chapter**

### **3.2.1) Background of concrete quality**

According to Doka (2008), the following criteria have been established in determining the finish quality of a formed concrete surface:

- Evenness and smoothness
- Surface structure which is flat, plumb and straight with sharp corners and edges
- The presence and extent of panel joint lines
- Presence of tie holes
- Concrete colour with regard to staining and discolouration
- Drip marks from grout loss onto previously poured surfaces
- Surface porosity and surface density
- The presence of steps in the concrete surface at the panel joints
- Leakage of fines at joints and tie holes (Watertight seals at joints prevent grout loss and excessive joint markings.)

It is necessary for the reader to understand the finish classes applicable to formed concrete surfaces. This text from the United States Bureau of Reclamation, (2009), defines the classes.

The classes of finish for formed concrete surfaces are designated by the symbols (F1, F2, F3, and F4). The classes of finish shall apply as follows:

- F1. - Finish F1 generally applies to formed surfaces upon or against which fill material, grout, or concrete is to be placed.
- F2. - Finish F2 generally applies to all formed surfaces not permanently concealed by fill material, grout, or concrete, or do not require a finish
- F3. - Finish F3 generally applies to formed surfaces, the appearance of which is considered by the Government to be of special importance, such as surfaces of structures prominently exposed to public view. This is after all required patching and correction of imperfections have been completed.
- F4. - Finish F4 generally applies to formed surfaces for which accurate alignment and evenness of surface are of paramount importance from the standpoint of eliminating destructive effects of water such as for suction or draft tubes.

[www.usbr.gov](http://www.usbr.gov) (Access April 15 2009)

### **3.2.2) Importance of concrete quality**

Concrete by itself has no shape or form. It is shaped and moulded by being placed in formwork. The formwork face in contact with the wet concrete determines the texture, shape, smoothness or roughness of the concrete surface. The prime purpose of formwork is to shape and mould concrete by containing its flow in its liquid state. But very often the formwork materials that perform this function cannot be relied upon to give a satisfactory surface finish. The selection of the formwork face is therefore critical in the visual appearance of concrete and it is the most important element in achieving concrete finishes. If the concrete mix is consistent throughout a project but the formwork is poorly constructed and panel joints are badly fitted, the support system is not rigid enough to adequately resist the pressure from the liquid concrete; then the surface appearance of the concrete will be poor. Formwork is also the most expensive element involved in concrete finishes and cost versus finish quality issues often arise.

<http://www.ecocem.ie> (Access 5 may 2009)

To use the words of *Nemati (2007)*:

“In designing and building formwork, the contractor should aim for maximum economy without sacrificing quality or safety. Size, shape and alignment of slabs, beams and other concrete structural elements depend on accurate construction of the forms.”

The forms must be:

- Sufficiently rigid under the construction loads to maintain the designed shape of the concrete
- Stable and strong enough to maintain large members in alignment, and
- Substantially constructed to withstand handling and reuse without losing their dimensional integrity.

The formwork must remain in place until the concrete is strong enough to carry its own weight or the finished structure may be damaged.

### **3.2.3) Effects of formwork on concrete discolouration.**

- **Staining, rust and discolouration of concrete elements formed with steel sheathing.**

The appearance of rust on steel formed concrete elements is an inherent possibility due to the properties of steel. Rust can appear on concrete for three reasons:

1. Rust already on the form surface that is not removed before the form is assembled.
2. The formation of rust on forms that are not protected from rain or other water before concrete is poured.
3. The formation of rust on the concrete surface when steel forms are left in place after the concrete is already set.

The first two are obvious and need little explanation. If a layer of rust is present anywhere on the formwork, and the concrete is poured into the form, the discolouration will be imparted onto the surface of the concrete. This is also true for any form of discolouration found on steel formwork, and is the reason that steel form faces are not painted to prevent corrosion, because by solving the one problem, another is created when the paint is imprinted onto the concrete surface.

Rusted or discoloured forms are best prevented rather than treated:

According to Concrete Producer Magazine, (2007);

“Removing rust mechanically, such as by sanding, can lead to "activated" steel surfaces, which are especially prone to rust.

The proper storage and sheltering of shutter material, as well as the proper application of release agent is important in this regard, but nobody can be blamed for unexpected rain causing rust on forms.”

The last formwork caused source of rust on formed concrete is when corrosion forms between the concrete and the form in the presence of air and water.

In the words of Concrete Producer Magazine (2007):

“There are several reasons for metal corrosion, and thus different forms: contact corrosion, crack corrosion, inter-crystalline corrosion, pitting corrosion, etc. The corrosion of iron and/or steel is an electrochemical process in the presence of water and oxygen. Metal corrosion occurs at the spot with the higher electro-negative potential. Here, the metal ions dissolve from the surface into the solution and when they collide with hydroxide ions they precipitate as iron hydroxide.

The resulting iron minerals are formed, depending on temperature and air humidity. Due to constant recrystallization, no permanent protective rust layer is formed on the surface that would prevent further corrosion.”

Basically, the steel form, together in the presence of air and water in the concrete initiates the corrosion process and rust appears on the formed concrete after curing.

- **Discolouration of concrete elements formed by timber sheathing.**

The major cause of unsightly discolouration on concrete elements formed by timber sheathing is a result of the absorbency of the timber face as a function of the moisture content of the timber.

The moisture content relies on the age, storage, protection and maintenance of the forms.

Along with a raft of other parameters, the absorbency of the surface of the formwork skin has a major effect on the surface of the concrete.

Absorbency has a number of positive effects such as fewer pores and less blushing, but it also has its downsides.

One effect that often gives rise to complaints becomes apparent if the formwork elements used on a structure have panels that vary in absorbency. The more absorbent the skin of the formwork sheeting, the darker the face of the concrete will generally be.

*Doka (2008).*

The individual panels in a single assembled form could vary in moisture content or the panels used to assemble another form for the same wall could vary in moisture content from those used for the previous pour. This will result in patches of lighter or darker concrete known as grey shade and ruins the possibility of a uniform surface appearance.



**Figure 19.**

The variation in the grey shade of concrete due to the absorbency of the timber formwork sheathing.

*Source: Doka 2008*

Proper planning and management of timber forms to prevent the timber from drying out in full sun or from becoming waterlogged, which also negatively impacts the useable lifespan, should enable the contractor to markedly reduce the effects of timber absorbency on concrete surfaces.

According to Doka, (2008):

The water absorbed either from the concrete or from weather-related precipitation produces changes in the formwork skin itself. The effects of these changes are most noticeable in the first three use cycles, because it is at this stage of its lifespan that the skin of the formwork undergoes the severest changes. The moisture balance of the formwork then settles to some extent, subsequent changes are no longer as severe and their effects are less noticeable.



### **3.2.4) Effects of formwork on the dimensional conformity of concrete elements**

The dimensional conformity of formed concrete is often very important, because services, aesthetic finishing and other successive building activities will be affected when concrete elements are skew, out of square, out of plumb, or not within dimensional tolerances.

If workmanship is removed from the equation, the two factors left to account for the dimensional conformity of formwork are the panel design and the assembly components. These have already been briefly discussed in Chapter 2 under design considerations, where it was concluded that modern computer aided design and sophisticated material and machinery have made the MTFs superior in the assembly of the forms, and this will ensure more accurately formed concrete elements.

### **3.2.5) Effects of formwork on surface regularity and smoothness.**

A key point to consider in the surface regularity and smoothness of concrete is that formed concrete, when properly placed and vibrated, will take the exact same surface appearance as the form within which it was molded. So once again, proper management and protection of formwork is essential to attain a quality formed concrete surface.

Even where the concrete is structural only, and will receive further finishing, a rough and untidy concrete surface is of little use. Where the concrete is to be plastered, a cautious contractor would still apply a bonding agent or slurry before plastering to ensure proper adhesion of the rendered finish. Where cladding is intended, irregular concrete surfaces can also cause fixing difficulties for masonry screws as well as causing the supporting framework to be skew and misaligned.

- **Effects of steel sheathing on surface regularity and smoothness.**

Steel, as used in formwork will always be smoother than any timber surface man has produced, and thus where an absolutely smooth concrete finish is required; new steel will always be the best. The downside of steel is that damage to the sheathing such as dents, holes, and other surface irregularities are very difficult and very costly to repair as a number of intensive operations such as welding and grinding are involved. Another method to repair holes and dents in steel forms involves patching with putty filler. The

authors experience has found that these patches easily flake off and the form surface appears un-refurbished.

Ecocem, (2009), sums up steel formwork

“Steel formwork is completely impermeable, and as such it can lead to the formation of blowholes in inadequately compacted concrete, as there is no route for the air to escape through the formwork. Steel will give a good quality, shiny finish to concrete, as long as the internal surface of the steel is smooth and free of markings.”

<http://www.ecocem.ie> (Access 5 may 2009),

- **Effects of timber sheathing on surface regularity and smoothness.**

Resin coated Timber sheathings as used in MTFS, provides a very smooth forming surface for concrete. It is close but no match for steel, but is still a vast improvement over uncoated timber.

One problem with timber facings regarding surface smoothness is again a function of the moisture content of the timber, and is best explained by

Doka, (2008): “Surface waviness. Coated birch plywood in particular can form irregular waves along the direction of the fibers when moisture penetration is non-uniform on account of tiny holes in the film coating or damage and nail-holes, and through the edges of the sheets. Although only a few tenths of a millimeter high, these waves are clearly perceptible in the surface of the concrete. The waves disappear when the panel has had a chance to balance its moisture content, and when next used the formwork produces a smooth finish.”

MTFS are much easier to refurbish as the sheathing is attached by means of screws or rivets, unlike steel forms where the face and framework are welded together. These fixings are easily removed and the damaged timber surface can be renewed.

The timber sheathings are resin coated both sides, so the first renewal will involve reversing the timber insert to reveal the new face, at a minimal cost.

When the second face of the timber has been exhausted, the whole timber panel is replaced with a brand new item from the manufacturer.

(Kretzman, 2009).

Although not recommended by manufacturers, in remote areas where support is difficult, these renewal operations can easily be accomplished by an experienced carpenter.

Ecocem, (2009), sums up timber formwork

*“Heavy Duty (or high density) Overlay Plywood (HDO)*

HDO plywood comprises a phenolic resin-impregnated cellulose fibre sheet bonded to the surface of the plywood. These formwork panels provide strength, rigidity and dimensional stability to the concrete, and are semi-resistant to alkalis, moisture penetration and abrasion. This type of formwork is most suitable where the highest quality finish is required, and can impart a nearly polished finish to the concrete. Up to 50 or more uses can be obtained.”

<http://www.ecocem.ie> (Access 5 may 2009)

### **3.3) Summary**

This chapter compared the properties of steel and resin coated timber as used for formwork sheathing to determine which material provides the best quality formed concrete surfaces. The quality of the formed surface was looked at in terms of discolouration for fair-faced concrete, as well as dimensional accuracy and the smoothness and regularity of the surface.

### **3.4) In conclusion**

Discolouration was found to be a potential problem that can affect both steel and timber sheathing to formwork. As in Chapter 2, the framed timber systems were found to be superior in ensuring the dimensional conformity and accuracy of the concrete element. Lastly it was shown that modern framed timber systems would provide a good quality finish for a longer lifespan, but for once-off extremely smooth concrete, new steel is the best choice as a formwork sheathing material.

The most apparent result of this chapter is that concrete quality is more reliant on the maintenance and protection of the formwork, and the workmanship and effort in assembling the forms. Even the best formwork will not provide quality surfaces if it is abused in storage, transit, erection and striking. Poor supervision and workmanship will have similarly negative effects on the surface produced.

This conclusion is supported by Concrete Producer Magazine, (2007):

“Formwork and the way it is used and handled affects the quality of the concrete and the concrete finish. Some of the bad effects that forms can potentially have on the surface are obvious - bad form joints, offsets or poor facing material - but others are not so commonly understood or appreciated. Not all differences in concrete surface appearance that are sometimes attributed to the forms, however, are actually caused by them.”

And again by Doka Plywood, (2008):

“The number of use cycles for high-quality concrete faces, however, depends heavily on the treatment received by the panels.”

### **3.5) Testing the hypothesis**

To restate the hypothesis:

New steel always provides the best possible concrete finish, but it deteriorates quickly.

The easily refurbished and replaceable faces of the timber systems should impart a better finish quality for longer.

The hypothesis has been shown to be true, new steel, as a sheathing will always provide a smoother concrete surface, but once it has been damaged, it is less easy to successfully restore, and for this reason, the resin faced timber sheathing will provide a better quality finish for a longer lifecycle.

## Chapter 4

### 4) Which system is the most durable?

#### 4.1) Introduction to the chapter

Investment in formwork represents a massive capital expenditure for any building or civil contractor and it would be wise for contractors to spend their money on formwork systems that are durable, long lasting and that offer many, quality pours provided they receive reasonable care and maintenance.

This is especially important in South Africa, where construction sites are often very rough places. Our poorly educated site labour and demanding site conditions mean that all forms of construction material and equipment are subject to serious misuse and abuse, and formwork is not excluded despite its high cost and the wishes of site management.

This chapter will compare the two chosen types of formwork systems in terms of their durability through regular use and the ease of refurbishment.

The sub-thoughts are therefore as follows:

- Sources of damage to formwork
- Material of the framework
- Material of the sheathing
- Material of the assembly components
- General maintenance and care.
- Refurbishment of formwork

## 4.2) Body of the chapter

### 4.2.1) Sources of damage to formwork

According to Zondo, (2009), the most common causes of damage to formwork are as follows:

- Handling and storage at the contractors central plant yard
- Loading, transporting and unloading the forms at the particular site or place of use.
- Improper crane or pallet lifting of the forms.
- Incorrect storage and protection of the forms on site when not in use.
- Incorrect assembly procedures and methods.
- Use of incorrect assembly components (This often happens when more than one formwork system is used on site and the clamps, walers, form ties etc are interchanged).
- Damage to sheathing caused by reinforcing fixing, electrical, plumbing and other trades.
- Excessive nailing into the facing of the forms, timber or steel.
- Damage to sheathing face caused by poker vibrators. I.e. Poker burn.
- Late, or improper striking of forms after concrete has cured.
- Insufficient post-concreting care of form panels.

### 4.2.2) Construction of the framework

#### • Construction of MTFS

The metal framework of the Doka Frami 300 and the Formscaff Tifa-Lite MTFS are both of mild grade steel that has been hot-dip galvanised. According to the American Galvanizers Association;

Hot dip galvanising is the process whereby fabricated steel, structural steel, castings, or small parts including fasteners are immersed in a kettle or vat of molten zinc resulting in a metalurgically bonded alloy coating that protects the steel from corrosion.

[www.galvanizeit.org](http://www.galvanizeit.org) (Access 01 July 2009).

The galvanising of the steel acts as a physical barrier that protects the steel from any form of corrosion, particularly rust. Galvanising is not just a coating like paint, but it is

much more durable because the zinc chemically bonds to the surface of the steel and forms a layer that cannot be damaged by chemicals, impact or abrasion.

The framework of the Peri Domino formwork is powder coated mild steel. Powder coating is the electrostatic application of a thermoplastic or thermo-polymer in a powder form to metal objects. It is then baked in an oven to form a membrane-like coating that is extremely tough and hard wearing. According to Wiki-pedia, (Access 01 July 2009), powder coating is very resilient and cannot be removed using common solvents or acids. Only 98% sulphuric acid and physical abrasion can damage the powder coating.

- **Construction of MSFS**

The framework of the steel formwork panels from Formscaff, Wiehahn and Uni-span are all constructed similarly of mild steel. This metal framework is factory spray painted with a primer and a single, coloured coat of alkyd paint. The paint is not at all hard wearing and the majority of used panels found on site have very little paint remaining.

#### **4.2.3) Material of the sheathing**

- **MTFS Sheathing**

All three of the MTFS are faced with a 15mm thick sheathing of engineered timber. According to Doka Plywood, (2009), these comprise 11 alternating ply's of birch or spruce that are cross laminated with a high performance adhesive that is boil proof, alkali proof, waterproof and weatherproof. Both faces of this timber are coated with a phenolic resin that produces an extremely smooth face for the formwork.

The resin facing is waterproof, and impervious to attack by the alkali in the concrete. This means the timber sheathings are very resilient and long lasting provided they are correctly maintained. For example, large nail holes that are untreated or un-patched would invite excessive moisture into the composite board, and while the adhesives are waterproof, the timber plies are not, and can warp or become totally destroyed.

- **MSFS sheathing.**

All the steel formwork panels have a mild steel sheathing that is only factory painted on the reverse side. The bearing face is not painted, as the caustic nature of the concrete would remove the paint from the steel and imprint it upon the formed concrete surface

#### **4.2.4) Material of the assembly components**

- **MTFS assembly components**

The assembly components of all the MTFS are either powder coated or galvanised similarly to the framework of the forms. The protective nature of these coatings applies as above.

- **MSFS assembly components**

The assembly components of the steel forms, i.e. tee and wedge sets, scaffold tubes, b and c-clamps, etc are all made of mild steel, and none is painted, galvanised or protected in any way. All of these components are extremely prone to rust and according to Scorgie, (2009), they are largely considered a consumable item as approximately 30 percent are lost, broken or discarded during construction.

#### **4.2.5) General maintenance and care.**

To ensure the maximum use out of formwork panels, certain tasks of post concreting maintenance should be carried out:

- Spilled concrete should be cleaned from the frames and the assembly components.
- The facing should be scraped free of concrete slush and latence.
- Formwork release agent should immediately be applied to the face.

*Kretzman (2009)*

#### **4.2.6) Refurbishment of formwork**

- **Refurbishment of MTFS**

According to Kretzman (2009), timber formwork panels are easily refurbished. All panels are scraped clean with a metal spatula, sprayed with high pressure water cleaners and then inspected. The typical repairs include patching holes and scratches in the timber facing, as well as straightening and aligning panels to ensure they are square and will assemble properly. The timber sheathings are attached to the metal frame by means of screws which are easily removed to allow the frame to be straightened in a hydraulic press. The timber sheathings have two good faces, so when the first face is badly damaged the timber can be turned around and re-fixed to the frame to provide a brand new sheathing at low cost.

Minor holes and scratches can be repaired using a plastic laminate patch. The damaged area is routed to accept the standard size and shape of the patch using a routing jig. The patch is then simply glued in place. To complete any refurbishment the silicone beading



between the timber face and the steel framework is reworked to ensure a tight seal with minimum loss of cement paste to cause unsightly joint lines.

- **Refurbishment of MSFS**

According to Knowles, (2008), the refurbishment of steel formwork such as Formscraft's economy panel is a labour and energy intensive process.

All panels are first inspected for damage before being sent to the appropriate repair bay. Typical repairs include straightening and aligning panels and repairing holes or dents in the face of the sheathing.

To repair holes in the sheathing, the holes must be filled with molten steel using a welding machine. The weld must then be ground flush using a die grinder until the repaired area is not noticeable. Dents and bumps are repaired by heating the panels and then beating them flat using a hammer against a solid backing. Other irregularities are filled using a polymer filling putty similar to that used in the automotive repair industry. According to Joubert, (2009), these patches do not survive the rough treatment of shutterhands, and the majority fall free from the panel after a couple of pours.

### **4.3) Summary**

This chapter compared the durability of the two types of formwork system by looking at the materials from which they are constructed to determine which system will best stand up to the elements and the rigours of use and abuse on construction sites. It also investigated the major causes of damage to formwork as well as the general care to be taken to ensure the longevity of the contractor's equipment. Lastly it briefly compared the refurbishment processes of the two systems.

### **4.4) Conclusion**

The metal framework and assembly component of the MTFS are well protected from physical damage and from the elements because of their tough and durable coatings which are far more resilient than the paint on the MSFS. The weakest link of the MTFS is the timber sheathing, which has quality timber, laminated with high quality waterproof adhesive and a water resistant resin face. Therefore its weakest link is hardly so weak at all.

The design of the MTFS allows for a much quicker and easier repair process with better results when compared to the energy intensive repair process of MSFS.

#### **4.5) Testing the hypothesis**

To restate the hypothesis:

The surfaces of timber faced forms are very susceptible to damage through physical battering and weather but are more easily repaired than the steel forms which dent and deform. This means the timber system should prove less durable, but longer lasting.

The hypothesis has proven true, in that the timber sheathings of the MTFS are easier to damage, yet at the same time are also easier to repair and refurbish, making them the longest lasting option.

## **Chapter 5**

### **5) Which system is the most economical for the contractor if comparing purchase and hire costs?**

#### **5.1) Introduction**

Financial investment in formwork is not accurately represented by the purchase cost of the equipment alone. There exist many other costs that are borne by construction contractors in owning, using and maintaining formwork.

These other costs include, but are not limited to; maintenance, storage, transport, insurance, and depreciation. These costs are however, too varied and too numerous for the purposes of this text.

This chapter will therefore compare the two formwork systems more directly by determining an average purchase and weekly hire cost of the two formwork systems. This will be done by sampling three price quotations of each type. Thereby proving which is the most economical to purchase or to hire.

After the direct costs have been compared and the most economical has been decided, the authors' opinion shall be put forward to apply the findings to reality in the industry.

## 5.2) Body of chapter

### 5.2.1) Purchase cost

The Purchase Price quotations for the wall formwork are based on the following requirements and conditions in order to produce comparable results:

- 50 square meters of wall formwork.
- Single straight section of 250mm thick Reinforced concrete wall.
- No crane, therefore no lifting hooks or lifting beams priced.
- All necessary components according to the supplier, including kickers, ties and stays.
- Purchase price is for brand new equipment
- Prices do not include pallets or coffers for transport.
- Prices do not include delivery costs.
- All prices are VAT inclusive.

The delivery cost for the formwork has not been taken into consideration, because the variability of this element should not be allowed to affect the results.

It should make no difference if the delivery costs of the different suppliers are varied, because most contractors provide their own transport to pick up and return the formwork, and the very similar size, weight and shape of the equipment means that the transport requirements will be as similar as to make no difference, (Kretzmann, May 2009).

#### • Purchase cost of MSFS

	Wiehahn Economy form	Uni-Span Economy form	Formscaff Econo-form
Purchase price in Rands,	<b>R 104 284.85</b>	<b>Refused to participate</b>	<b>R 126 066. 27</b>
Average purchase price in Rands,	<b>R 115 175. 56</b>		

**Table 3. Price quotations for purchase of steel wall formwork**

*Source: Author*

- **Purchase cost of MTFS**

	Peri Domino	Doka Frami 300	Formscaff Tifa-Lite
Purchase price in Rands, excluding delivery, including VAT.	<b>R 303 055. 41</b>	<b>R 207 567. 19</b>	<b>R 335 808. 73</b>
Average purchase price in Rands, excluding delivery, including VAT.	<b>R 282 143. 77</b>		

**Table 4. Price quotations for purchase of timber wall formwork**

*Source: Author*

- **Comparison of Purchase costs.**

A comparison of the purchase costs of MSFS and MTFS shows the MTFS to be substantially more expensive. With an average purchase cost of R 282, 143. 77 for Timber faced formwork compared to the average purchase cost of steel faced formwork at R 115, 175. 56. This equates to the timber form systems being, on average 145 percent more expensive.

For a more apparent contrast, compare R 5, 642. 87 / M<sup>2</sup> for timber formwork versus R2, 303. 51 / M<sup>2</sup> for steel formwork.

These greater costs are undoubtedly the result of the more advanced design, engineering and materials that are used in the manufacture of the timber faced form systems.

### 5.2.2) Hire cost

The hire cost quotations for the wall formwork are based on the following requirements and conditions:

- All Prices are per 7 day week, including all holidays and public holidays.
- 50 square meters of wall formwork.
- Single straight section of 250mm thick Reinforced concrete wall.
- No crane, therefore no lifting hooks or lifting beams priced.
- All necessary components according to the supplier, including kickers, ties and stays.
- Hire cost is for equipment in a reasonable useable condition there is no guarantee of receiving new equipment.
- Prices include pallets and coffers for transport.
- Prices do not include delivery costs to site, nor return delivery costs to the supplier.
- All prices are VAT inclusive.

- **Hire cost of MSFS**

	<b>Wiehahn Economy form</b>	<b>Uni-Span Economy Form</b>	<b>Formscaff Econo-Form</b>
Hire cost in Rands per week, excluding delivery, including VAT.	<b>R 3 446. 61</b>	<b>Refused to participate</b>	<b>R 4 167. 48</b>
Average Hire cost in Rands per week, excluding delivery, including VAT	<b>R 3 807. 05</b>		

**Table 5. Price quotations for hire of steel wall formwork.**

*Source: Author*

- **Hire cost of MTFS**

	<b>Peri Domino</b>	<b>Doka Frami 300</b>	<b>Formscaff Tifa-lite</b>
Hire cost in Rands per week, excluding delivery, including VAT.	<b>R 3 828. 00</b>	<b>R 3 088.11</b>	<b>R 4 231. 19</b>
Average Hire cost in Rands per week, excluding delivery, including VAT	<b>R 3715. 76</b>		

**Table 6. Price quotations for hire of timber wall formwork.**

*Source: Author*

- **Comparison of hire costs**

Contrary to the findings of the purchase costs, the hire costs have unexpectedly favoured the MTFS.

The Steel formwork prices at an average of R 3, 807. 05 / Week, and the Timber formwork beats that price with an average of R 3, 715. 76/ Week.

Compare R 76.14/M<sup>2</sup>/Week with R 74. 31/M<sup>2</sup>/Week.

That means that in this case, the MTFS is two and a half percent cheaper to hire, which is not a substantial difference, but nonetheless is an impressive result considering the notably higher purchase costs of the MTFS.

### **5.2.3) Discussion of Purchase and Hire costs.**

The massive cost saving in purchasing steel formwork over timber formwork explains very well, why large civil contractors would rather purchase steel formwork than timber formwork.

Economically it is more sensible to purchase the equipment that has a far cheaper purchase price, yet is a product which has been around for many years and proven itself to function and last reasonably well.

According to Craig Cock, (July 2009), Civil engineering contracts use a lot of shutter for long periods of time, so it is economically advantageous to purchase and keep cheaper steel formwork in their own plant yards, than to purchase or to hire timber shutters.

The sizeable advantage of this is proven by the fact that a steel economy form panel hired from Wiehahn formwork, costs the contractor R61, 83 per week per panel to hire, whereas according to Rob Muirhead (April 2009) a Grinaker-LTA site pays approximately R 2, 00 for that same panel per week.

This is because the materials were purchased and depreciated very rapidly over the first few jobs they were used on.

Now, due to their durability, the panels have practically zero cost to the company and the sites' can reap this massive benefit.

The lower hire cost of MTFS proves the suppliers' own belief in the quality and durability of their timber formwork systems. Despite the high purchase price, and hence production cost of the equipment, they are satisfied to hire it out for a lower price than that of the price for steel formwork.

### **5.3) Summary**

In summary, it was shown, that steel formwork is vastly cheaper to purchase than timber formwork. Intriguingly, it was found that the hire costs of the two types of formwork are very similar, with the surprising result that MTFS is on average two and a half percent cheaper than MSFS to hire on a weekly basis.

### **5.4) Conclusion**

To conclude, the MSFS is undoubtedly the more economical formwork for a contractor to purchase for purposes of crane-less assembly of forms for vertical concrete elements. Conversely, MTFS have lower the hire costs for the same equipment. This shows that the manufacturers have confidence in their timber formwork systems to last well and provide a long useable economic life.

With the purchase costs and hire costs each favouring different formwork systems, it has not been proven beyond doubt that either system has a noticeable advantage in terms of system economy. The economy of the system is dependant on whether it is purchased or hired.



## **5.5) Testing the Hypothesis**

To restate the hypothesis:

The longer life cycle obtained from timber faced forms, as well as the cost saving which results from reduced erecting and striking times will make them the more cost effective option for the contractor over time.

It has not been proven conclusively that timber formwork systems are the more cost effective option for contractors. The hypothesis has not proven true.

# Chapter 6

## 6) Final summary

### 6.1) Background

- **Re-stating the main problem:**

Vertical concrete elements: Are modern modular timber formwork systems better than the old modular steel formwork systems?

The initiative of this research text is to show that the modern day design and material advancements used to design and manufacture timber formwork systems has ensured that they truly are a better way for building and civil contractors to form vertical concrete elements such as columns, stopped-ends, shear walls and others.

Substantial cost and time savings can be had by carefully selecting the most suitable formwork system and as such this text should answer some important questions.

The research was done by directly comparing a sample of locally used timber formwork systems with a similar sample of steel formwork systems to determine which is ultimately the superior equipment based on the type of formwork, and not the manufacturer of the formwork.

### 6.2) Summary

- **Chapter 2**

The text focused on the physical design and ergonomic aspects of the two types of formwork systems with the following findings:

- Firstly, the systems were compared in terms of the average weight per m<sup>2</sup> of panel and it was shown that MTFS panels are on average nine and a half percent lighter than MSFS panels.
- Secondly the dimensional and physical design aspects of the two systems were compared and it was easily proven that the MTFS are ergonomically superior to the MSFS in terms of carrying and lifting and they are undeniably

the least strenuous on the workers.

- The final aspect of chapter two showed that the assembly components of the MTFS were far superior to those of the MSFS in that they are easier and quicker to use and they ensure a more secure shutter assembly with a lower risk to personal safety.

### • Chapter 3

The research focused on the quality of the concrete finish provided by the two different formwork systems.

- It was first shown that the MTFS is less likely to cause discolouration of the concrete face.
- Secondly it was shown that the MTFS provided a superior dimensional conformity of the concrete element. This is due to alignment clamps and compensating walers providing tighter joints with better alignment of individual panels.
- The MSFS was found to be more susceptible to the formation of blowholes and honeycombing on the formed face due to the complete impermeability of the steel face restricting the escape of air bubbles and air pockets during vibration of the concrete. This was not as severe with MTFS due to the semi-impermeable resin faced timber.
- Lastly it was found that the MSFS, if new, would produce a smoother concrete face than MTFS, but that the MTFS would provide smoother concrete faces for longer due to the easy repair and refurbishment of the timber sheathings.

### • Chapter 4

This chapter compared the two formwork systems, namely MTFS and MSFS to determine which system is the most durable and will provide the longest economic life.

- Firstly the two systems were compared to see which had the most robust and durable framework. The MTFS was shown to be far superior in this regard with thick hollow profile frames that are either powder coat or galvanized to protect the surface steel from any corrosion. The unprotected steel of the MSFS is very prone to rust and the panels must be cleaned and oiled regularly to ensure they last.
- Secondly the Sheathing materials were compared, with the result that the HDO

engineered timber sheathings were less durable than the steel sheathings of the MSFS due to the ingress of water which can cause the timber to swell and deteriorate.

- Third, the assembly components were compared, and the findings showed that with MSFS, the assembly components lack any protective coating and due to their smaller size are often lost or inadvertently discarded, Whilst the assembly components of the MTFS are larger, more robustly built and all are powder coated or galvanized to ensure longevity.
- Finally, a brief look at the refurbishment processes of the two systems showed that MTFS panels are a lot simpler to refurbish and repair once damaged when compared to the MSFS which require long intensive processes to restore damaged form panels.

- **Chapter 5**

This chapter comprised a cost comparison between both purchase and weekly hire costs for the formwork. The quotations were based on identical quantities of materials and Rands per meter squared price was then calculated.

- Firstly it was found that MTFS is substantially more expensive to purchase than MSFS, with an average purchase price that is 145 percent higher.
- Secondly it was discovered that the MTFS was cheaper to rent than MSFS, but that the cost discrepancy was minimal, with MTFS only being two and a half percent cheaper to hire than MSFS.
- The final conclusion of this chapter was that the other advantages of MTFS, as proven in previous chapters, should outweigh the higher purchase costs, but this opinion cannot be forced upon anyone. Secondly the cheaper hire costs mean that the use of MTFS should begin to see more regular use in our country.

### **6.3) Conclusion**

In concluding, the following must be mentioned:

Chapters two, three and four were ultimately concluded in favour of the timber formwork, whilst chapter 5 could not be said to favour either system more than the other. Seventy five percent is a success for the timber formwork to prove itself as the superior concrete forming system in all respects except that of cost. The conclusion therefore, is that the

main problem has been solved by proving modular timber formwork systems superior to modular steel formwork systems.

#### **6.4) Suggestions for further research**

The following two suggestions are put forward for future research to further improve the position of the MTFS:

- Time trials and physical observation should be used to produce accurate production rates using timber formwork and steel formwork. These can then be compared to prove and quantify the expected productivity increases offered by the MTFS. Such information does undoubtedly already exist within contractors and formwork manufacturers, but they all consider it confidential and none were willing to provide such information for this research.
- Proper life cycle costing should be performed to accurately determine whether the superior materials used in the construction of the MTFS will justify the higher initial cost when looked at over the lifespan of the equipment.

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