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# DECISION MAKING ON THE OPTIMISED CHOICE OF PNEUMATIC FORMWORK TEXTILE FOR FOAM-FILLED STRUCTURAL COMPOSITE PANELS

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**ABSTRACT:** The selection of an appropriate formwork system not only affects the entire construction duration and cost, but also affects subsequent construction activities such as electrical, mechanical, and finishing work. The current intuitive judgment approach in the selection of fabric formwork systems cannot assure an optimal and consistent result. This paper introduces a decision-making method for selection of the most appropriate pneumatic fabric formwork for foam-filled structural panels in rapidly assembled buildings (RABs) that will be used in semi-permanent housing such as post disaster sheltering. First, using a questionnaire survey, six most effective criteria for a suitable pneumatic fabric formwork; permeability, strength, relative cost, durability, sew-ability, and aesthetics are identified. Some experimental tests were conducted to determine the selection indicators for the criteria like durability and strength for each candidate. Then a value matrix for these factors has been defined and calculated, and the best pneumatic formwork candidate for foam-filled structural composite panels is selected from a list of seven potential candidates, using Analytical Hierarchy Process (AHP).

*Keywords: Fabric formwork, Pneumatic formwork, Foam-filled panels, Rapid assembly buildings, Decision making, Analytical hierarchy process*

## 1. INTRODUCTION

Fabric formwork is a method for construction of a wide range of architectural and structural components. Fabric formwork is made of textile sheets of synthetic fibres such as nylon, polyesters, polypropylene that are fabricated into containers to contain various type of fillers such as concrete. Fabric formworks can be used to form columns, walls, beams, trusses, slabs, panels, and thin-shell structures in both precast and in-situ construction. Using fabric formwork as a mould in concrete structures, it is possible to cast architecturally interesting, structurally optimized non-prismatic structures that use up to 40% less concrete in comparison with an equivalent prismatic section [1], offering potentially significant embodied energy savings [2] and subsequently, a striking reduction in the $CO_2$ emissions [3] can be achieved. In a recent ongoing research project at the Centre for Infrastructure Engineering of Western Sydney University, fabric formwork has been used for an innovative foam-filled structural panels in order to be employed for rapidly assembled buildings as a semi-permanent housing system. This study will focus on the pneumatic fabric formworks, in which pneumatic force is used for the erection of the flexible fabric formwork [4]. This system is going to tackle the problems with the existing semi-permanent housing systems' low tolerance in construction, transportation, erection and maintenance phases, as well as their relatively costly materials [5], installation and fabrication methods and labour works. The critical aspect of fabric formwork for achieving desirable performance is the selection of the fabric itself. Although a wide range of woven fabrics can be used as formwork for fabric formwork, tensile strengths in both warp and weft directions must be sufficient to hold the infill material (which is polyurethane [6] in this research) and a low creep modulus is desirable to limit formwork deformations during casting and curing/hardening. In the literature, to date, there is no known study based on systematic decision making methods for fabric formwork selection. This paper identifies the factors influencing the selection of an appropriate fabric, and develops a decision-making system for selecting the best fabric formwork textile for the newly developed foam filled panels, which will be used as a rapidly assembled building system for semi-permanent housing.

## 2. BACKGROUND OF THE STUDY

There are not many studies on the structural applications of fabric formworks. The work of Lamberton in 1968 in the field of Geotextiles led to the first commercial use of fabric formwork for concrete structures [7]. In the early 1990s, Rob Wheen from the University of Sydney and

Asaddoah Redjvani, developed a flexible formwork wall system for both the Persian Gulf and Caspian sea marine and land construction projects using PVC coated polyester fabric internal ties [8]. Ghaib et al. [9] showed that the mechanical characteristics of fabric formwork affect its filled material. Appropriate selection of a formwork system can considerably affect the cost and speed of many construction projects [10-14]. Shin et al. [15] proposed a decision support model to select a formwork system suitable for the construction site conditions. Optimisation and durability in fabric cast double T-beams have been studied by Orr et al. [16]. Proverbs et al. [17] identified nine formwork selection factors including quality of concrete, relative costs, speed of production, availability of plant and equipment, availability of labour, company practice, building form and location, degree of repetition and on-site transport system and ranked them in terms of importance for each international group of contractors. The formwork systems can be selected based on some construction considerations including easy and economical transportation from factory to construction site, easy and economical assembly and disassembly, maximum rate of construction speed to formwork weight, minimum number of construction joints, minimum waste generation in formwork production process, safety, ease of storage, applicability to high rise structures, reasonable potential for preconstruction, the potential to make non-prismatic sections and complex shapes, not reliant on highly-trained and skilled work force, compatibility with the core material in order to minimize the environmental effects, appropriate specific heat capacity and thermal conductivity, reusability and finally fast connectors applicability [18].

## 3. FABRIC FORMWORKS

### 3.1 Fabrics Properties

There are two general types of fabric formworks: slack-sheet mould and energized (tensioned) formwork sheets [19]. Fabrics can be categorised as woven/non-woven fabrics, balanced/unbalanced fabrics, knit fabrics, plastic films and coated/uncoated fabrics. There are many different weaving patterns but the basic pattern called a "plain weave" consists of warp threads (running along the long direction of the roll) and weft threads (filling transversely across the width of the roll) [19]. If a woven textile has the same amount of materials in both the wrap and weft directions, it is referred to as a "balanced" weave. An "unbalanced" weave will have more material in one direction that in the other, and so will have unequal strength and stiffness as well. Because the threads are kept straight, plain woven structures do not allow much stretching at all along the two axes of the weave. Nevertheless, a balanced plain woven fabric will always be slightly less stretchy (i.e. have greater stiffness in tension) in the warp, or machine direction [19]. Non-woven fabric such as felt generally refers to a fabric composed of short fibres, matted and compressed together in what might be described as a structural tangle. Non-woven textiles are not generally used structurally, as they are inherently weaker than woven fabrics, due to their randomized and non-continuous fibres. Knit fabrics are made with a looped thread running in a long meandering course, forming an interlinked mesh. Because the yarns are looped and not straight, a knitted structure allows a good deal of stretch. Plastic films are flexible sheets of plastic, such as a polyethylene vapour barrier film can also be used as a formwork sheet or as a formwork liner. Woven or even knit fabrics can have a waterproof coating applied to one or both sides. Such a coating affects the permeability of the fabric, for example, by making it impervious to water and air. Coating can also inhibit or prevent the threads from fraying at the edges of the cloth, and inhibit or prevent the fabric's fibres from "shearing" on the bias. When a coating is applied to a woven textile, it binds the woven tapes or threads together, fixing the weave's 90° geometry in place. Since the coating prevents, or inhibits, the threads from shearing, the fabric behaves less like a woven structure and more like an isotropic sheet such as a sheet of plastic or a piece of paper [19].

### 3.2 Fabrics for Flexible Formwork

Generally speaking, the viscosity of the fill material, the internal construction details, the hydrostatic pressure action on the outer skin, the internal restraints on the grout level, the size and shape of flexible formwork and its methods of placing and handling, the effects of buoyancy and currents, the sequence of injection, the position of bleed points or overfill prevention and finally, the provision of overfill compartments to compensate for the settlement of grout resulting from excessive bleed are the major factors to be considered when selecting fabric formwork [20]. Current construction practice in this field generally uses woven polyolefin textiles. Polyester, Polyamide, Polypropylene (PP) and Polyethylene (PE), which are not true elastic materials, are the main synthetic polymers used as raw materials to manufacture formwork fabrics [21]. Woven Polyolefin Geotextiles (PP and PE) are a common choice for fabric formwork. PE and PP textiles (that are made from woven high density polyethylene or polypropylene (HDPE or HDPP) threads or tapes) are among the least expensive options, while they are stronger and more robust than the burlap/hessian fabrics. PP fabrics don’t tear easily and are relatively lighter than PE. PE fabrics are resistant to strong acids or strong bases and relatively weaker in strength compared to PP. These materials can be manufactured with varying degrees of quality. Even the lowest quality PP and PE fabrics, such as woven textiles used for sandbags or packaging, will work well as fabric moulds, if used conservatively. There is also a wide range of PE and PP “geotextiles” manufactured for use in landscape construction and road building. These are made of woven high density polyethylene or polypropylene threads or taps and are specifically designed for combinations of strength and permeability to water. PE and PP are so similar in their appearance, handling and performance as formworks, that user will not be able to tell them apart. One weakness of PP and PP fabrics is that they will eventually degrade from exposure to ultraviolet radiation (sunlight), although they can be manufactured with anti-UV stabilizers that do a good job of resisting this degradation. The woven PE and PP fabrics are quite strong and will usually have plenty of reserve strength. Their behaviour is non-linear, with a rough service strain of above 2%. Linear, elastic behaviour may be maintained to 5% strain, or more. PP or PE woven fabrics will not propagate a tear, which makes them safe to use, and allows them to be connected using staples, screws or nails. PP and PE are also thermoplastics.

## 4. STUDIED FABRICS

The textile industry is developing various types of suitable fabrics for applications in construction [22]. In order to be used as a fabric formwork for structural panels, the most important properties of fabrics are strength, stiffness, failure mode (slow/plastic failure are more desirable than sudden/elastic failure), permeability, weldability (coated PE or PP fabric can be heat-welded together and uncoated fabrics cannot), reusability, easy sewing , and stress distribution ability. Accordingly, in this study seven types of fabrics that meet the abovementioned criteria, and are widely used for similar purposes have been selected and then evaluated as potential options for fabric formwork of foam filled panels. The selected fabrics were: Lockram, Hydrophobic Polyester Fabric, Laminated Chamois, Vinyl Crystal Clear, Rubber fabric, Herculon Fabric, and Barrateen (left to right in Fig.1).

Lockram is made from a semi-industrial type of cotton, and produced in 145 cm wide rolls. The common applications are household applications. This fabric is a balanced woven fabric, and has the identical tensile strength in both the warp and weft directions and is well inflatable too. The result of tensile tests according to ASTM D1980-89 in warp direction is shown in Fig.2. The applied width of specimens is 10cm and mechanism of failure is sudden/brittle rupture. The failure strain has been measured as 15%.

Fig.1 Studied fabrics

Hydrophobic Polyester Fabric is made from pure polyester and is 100% washable and mould resistant, and produced in 260 cm wide rolls. Its common applications are household applications such as curtains.

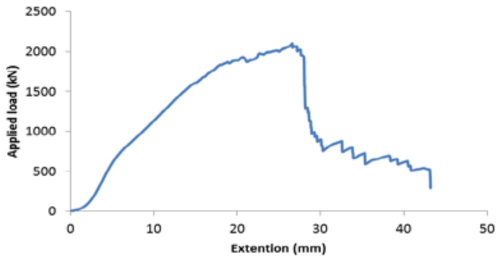


Fig.2 Lockram tensile behaviour

This fabric is a balanced woven fabric. It has the same tensile strength in both the warp and weft directions, and is well inflatable. The result of tensile tests on 10cm wide specimens according to ASTM D1980-89 in warp direction is shown in Fig.3. The failure strain has been measured as 17%, and the mechanism of failure is a sudden/brittle rupture. Laminated Chamois is composed of a plastic film and a layer of non-woven compressed to each other. It is used for household applications and produced in 135 cm wide rolls. By using as internal fabric formwork layer, the cost of finishing and maybe painting can be reduced. The result of tensile tests on 10cm wide specimens according to ASTM D1980-89 is shown in Fig.4, which shows that its failure strain is about 110%. Laminated Chamois is crimped during the tensile test, but at rupture point, only its plastic layer was ruptured and its un-woven layer kept deforming. The mechanism of failure is a ductile rupture. Vinyl Crystal Clear is an un-dyed polymeric fabric, used for household and produced in 135cm wide rolls. Because of its tensile behaviour and high failure strain (350%) and good stress distribution ability, as shown in Fig.5, it can be suitable for mechanical connections.

Rubber fabric does not display any plastic behaviour during tensile tests. Its fracture mode is very brittle (Fig.6) but, the failure strain has been measured as 90%. This brittle behaviour can create some structural problems when used for mechanical connections. It is produced in 100 cm wide rolls. Herculon fabric is a woven polyolefin textile, used as window shades, children's sandbox cover, pergola, veranda and patio cover, and produced in 185 cm wide rolls. It possesses relatively high strength and durability, and as a lead-free material has 100% UV-stabilised yarn and can reduce the UV flow by 90%. It is classified as mould and mildew resistant and non-shrink heat fabric and is not inflatable.

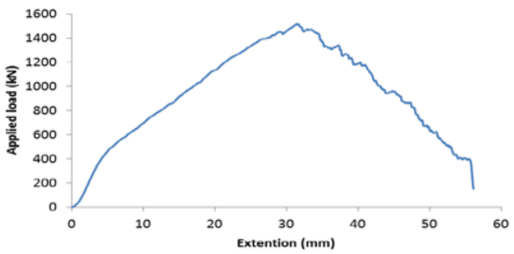


Fig.3 Tearing of Hydrophobic Polyester Fabric and its tensile behavior

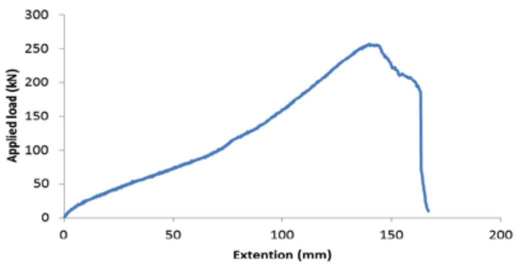


Fig.4 Laminated Chamois tensile behaviour

This fabric is an unbalance plain woven fabric. Therefore its tensile strengths in two directions perpendicular to each other (the warp and weft directions) are not the same. The result of tensile tests according to ASTM D1980-89, is shown in Fig.7. As Shown in Fig.9, before strain reaches 75%, Herculon fabric has similar behaviour in the two directions. Then, before reaching 225% strain, it has elastic behaviour in both directions. Under strains between 75% and 225%, the modulus of elasticity of the principal direction is higher, but, under the strain of 225% the harder specimen had a sudden rupture, whiles the softer specimen continues its deformation to about 250% strain.

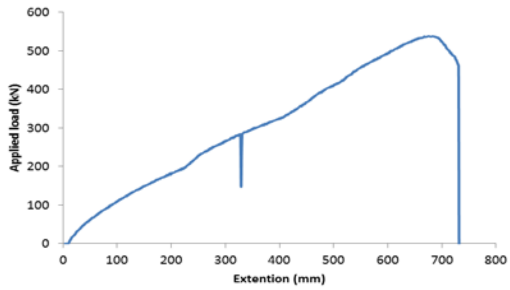


Fig.5 Vinyl Crystal clear tensile behavior

Barrateen is a HDPE coated unbalance woven textile. It is produced in 184 cm wide rolls. The coating material is low density polyethylene and well inflatable. In addition, its tensile strengths in the warp and weft directions are not the same. The result of tensile tests according to ASTM D1980-89 is shown in Fig.10. As can be seen in Fig.8, the modulus of elasticity of the principal direction is higher, but, under the strain of about 270%, both specimens had a sudden brittle rupture. As maintained before, weldability is one of the main benefits of the coated fabric. A series of weldability tests was also conducted on the fabrics (Fig.9).

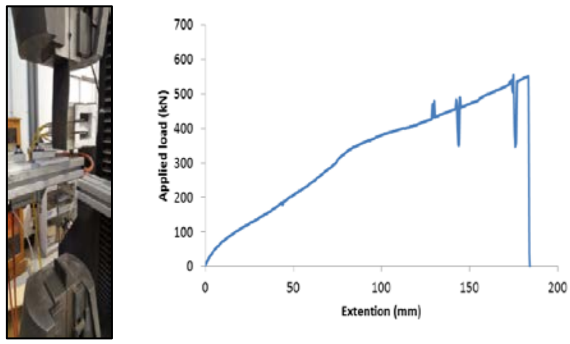


Fig.6 Brittle behaviour of Rubber fabric specimens

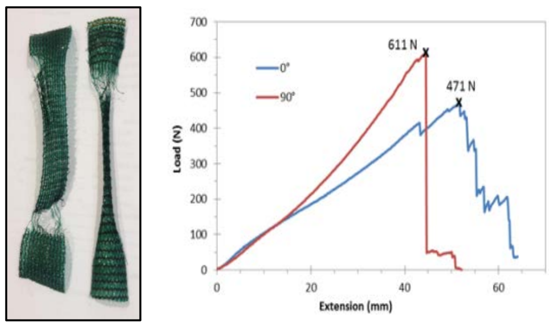


Fig.7 Herculon fabric tensile behaviour in main (90°) and transverse (0°) directions

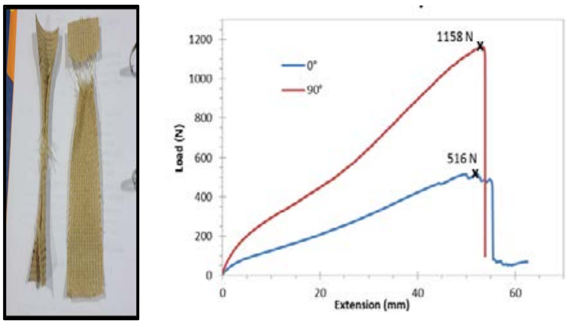


Fig.8 Herculon fabric tensile behaviour in main (90º) and transverse (0º) directions

The results of tensile tests of heat-welded parts showed that this kind of connections has no reliable structural performance (Fig.10). According to the results, the tensile bearing capacity of heat-welded connections can reach up to 13% of the average strength of the material. In addition, the maximum strain was measured as 90% at the failure point.

Fig.9 Heat-welded specimens of Barrateen fabric

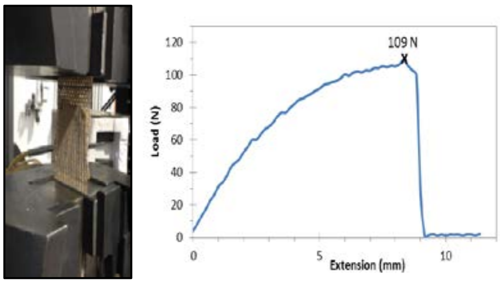


Fig.10 Tensile behaviour of heat-welded Barrateen fabric specimens

## 5. DECISION MAKING

Most real-world decisions are not limited to unique and single solutions. The decisions are typically less than optimal and are drawn from a set of reasonable alternatives that have been known as 'satisficing' solutions [23-25]. Therefore, the potential range of rational alternatives should be identified and classified [26]. In this case, selection of the most suitable fabric involves a case-by-case assessment to determine the potential risks associated with any given alternative. Potential users and decision makers have various criteria and constraints that must be coped with when endeavouring to suggest the best possible alternative. The main idea of using criteria is to quantify the performance of alternatives in relation to the objectives of the decision maker based on a numerical scale [27, 28].

### 5.1 Decision Criteria

The selection of an appropriate formwork system is mainly dependent on the intuitive and subjective opinion of practitioners with limited experience. In this study a survey and semi-structured interview with 30 potential users and specialists have been conducted. Based on this survey, the following six constraints/criteria for a suitable pneumatic fabric formwork are selected: permeability, strength, relative cost, durability, sew-ability, and finally aesthetics (Table 1). For scoring of durability, fabrics' resistance was examined against freezing and thawing. Three samples have been tested for different weather conditions. The process has been conducted three times within the interval of two days. At the next step, tensile strength tests were conducted on the specimens and the ratio of rupture force to tensile strength of the fabrics were measured. The average of the above-mentioned ratios was used as an indicator of the overall durability (Table 2).

### 5.2 Application of Analytical Hierarchy Process (AHP) for Decision Making

AHP is a multi-attribute decision making method which belongs to a broader class, known as "additive weighting methods". The AHP was proposed by Saaty (1977) [29] and uses an objective function to aggregate the different features of a decision problem [28, 32] where the main aim is to select the action item that has the highest value of the objective function. The AHP is based on four axioms[30].

Table 1 Rating of the decision alternatives against the major criteria (7 = best rank)

| | Lockram | Hydrophobic Polyester | Laminated Chamois | Vinyl Crystal Clear | Rubber Fabric | Herculon | Barrateen |
|---|---|---|---|---|---|---|---|
| Aesthetics | 5 | 6 | 7 | 2 | 1 | 3 | 4 |
| Permeability | 2 | 3 | 5 | 6 | 6 | 1 | 4 |
| Sew-Ability | 6 | 7 | 5 | 2 | 1 | 3 | 4 |
| Relative Cost | 1 | 1 | 1 | 1 | 1 | 2 | 2 |
| Durability | 2 | 3 | 1 | 4 | 4 | 4 | 4 |
| Strength | 6 | 5 | 1 | 2 | 2 | 3 | 4 |

Table 2 The ratio of after freezing-thawing tensile strength to natural tensile strength ($F_f$/ $F_n$)

| FABRIC | (%) $F_f/F_n^*$ |
|---|---|
| Lockram | 90 |
| Hydrophobic Polyester | 94 |
| Laminated Chamois | 86 |
| Vinyl Crystal Clear | 99 |
| Rubber fabric | 99 |
| Herculon | 99 |
| Barrateen | 99 |

Similar to MAU/VT and SMART, the AHP is classified as a compensatory method, where criteria with low scores are compensated by higher scores in other criteria, but contrasting the utilitarian systems, the AHP uses pairwise comparisons of criteria rather than value functions or utility where all individual criteria are paired with all other constraints and the end results accumulated into a decision matrix[31]. The process of AHP includes three phases: decomposition, comparative judgments, and synthesis of priority. Through the AHP process, decision problems are decomposed into a hierarchical structure, and both qualitative and quantitative data can be used to derive ratio scales between the decision elements at each hierarchical level by means of pair wise comparisons. The top level of hierarchy characterises overall objectives and the lower levels correspond to criteria, sub-criteria, and alternatives. With comparative judgments, decision makers are requested to set up a comparison matrix at each hierarchy by pairwise comparison of criteria or sub-criteria. A scale of values, ranging from 1 (indifference) to 9 (extreme preference) is employed to express the users' priority.

Finally, in the synthesis of priority stage, each matrix is then solved by an eigenvector method for defining the criteria importance and alternative performance [32]. The comparisons are normally documented in a comparative matrix A, which must be both transitive such that if, $i > j$ and $j > k$ then $i > k$ where i, j, and k are alternatives; for all $j > k > i$ and reciprocal, $a_{ij}=1/a_{ji}$. Priorities are then estimated from the comparison matrix by normalising each column of the matrix, to develop the normalised primary right eigenvector, the priority vector, by $A.W=\lambda_{max}.W$; where A is the comparison matrix; W is the principal Eigen vector and $\lambda_{max}$ is the maximal Eigen value of matrix A [31, 33]. Through the AHP process, decision-makers' inconsistency can be estimated via consistency index (CI) which is employed to determine whether decisions break the transitivity rule, and to what extent. A threshold value of 0.10 is acceptable, but if it is more than that then the CI is calculated by using the consistency ratio CR= CI/RI where RI is the ratio index. CI is further defined as $CI=((\lambda_{max}-n))/((n-1))$; where $\lambda_{max}$ is as above; n is the dimension [31]. The average consistencies of RI from random matrices are shown in Table 3. The advantages of the AHP method are that it has a systematic approach (through a hierarchy) and presents an objectivity and reliability for quantifying weighting factors for criteria [34]. It can also deliver a well-tested method which allows analysts to include multiple, conflicting, non-monetary features of alternatives into their decision making[35].

On the other hand, the disadvantages are that the estimation of a pair-wise comparison matrix for each attribute is complicated and as the number of criteria and/or alternatives increases, the complexity of the estimations increases considerably. Moreover if a new alternative is added after finishing an evaluation, it is very difficult because all the calculation processes have to be restarted again [34]. The shortcomings of AHP are of a more theoretical nature, and have been the subject of some debate in the technical literature. Many analysts have pointed out that, the attribute weighting questions must be answered considering the average performance levels of the alternatives. Others have noted the possibility for ranking reversal among remaining action items after one is deleted from consideration. Finally, some theorists go so far as to state that as currently practiced, "the rankings of AHP are arbitrary". Defenders of AHP, such as Saaty himself, justified that rank reversal is not a fault because real-world decision-making shows this characteristic as well [36].

Table 3 Random Inconsistency Index, Adapted from[37]

| N | 1 | 2 | 3 | 4 | 5 | 6 | 7 | 8 | 9 | 10 |
|---|---|---|---|---|---|---|---|---|---|---|
| RI | 0 | 0 | 0.58 | 0.9 | 1.12 | 1.24 | 1.32 | 1.41 | 1.45 | 1.49 |

**5.3 Strategy Selection Using AHP**

Through the AHP process, the problem under consideration is broken down into a hierarchy, including at least three major levels: goal, criteria (objectives) and alternatives. The criteria might be general and are required to be broken down into more specific sub-criteria introduced as attributes in another level of hierarchy. AHP deals with identifying the overall goal and proceeding downward until the measure of value is included. Fig.11 shows a four-level hierarchy structure considering the general features of the problem. The first level of the structure is the overall goal of the ranking (Fabric Selection). The second level contains the identified objectives (criteria) to achieve the main goal. The third level holds the sub criteria to be used for assessing the objectives. The final level is added for the alternatives [35]. Each criterion/constraint has a weighting indicating its significance and reflecting the organizational policy. These weightings are defined by the users/decision makers employing the pair wise comparison approach embedded in the AHP and will vary for different problems with different decision makers [29, 30]. The AHP has the major advantage of allowing the decision makers to conduct a consistency check for the developed judgment in regard to its relative importance among the decision making components. Therefore, the decision maker(s) can modify their evaluations to improve the consistency and to supply more informed judgments under consideration.

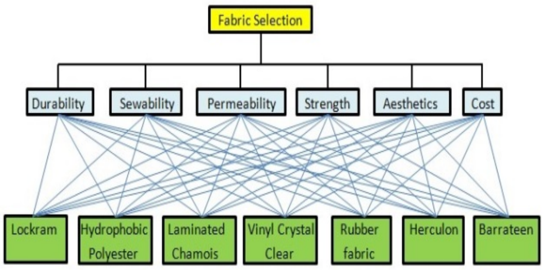


Fig.11 Multi Criteria Decision Hierarchy for Fabric Selection

The procedure is also able to provide flexibility in selecting the criteria to evaluate the alternatives (different types of fabric) and even increasing or decreasing the number of levels (associated with the criteria) in the hierarchy. The overall ranking value of each alternative for a four level hierarchy (as shown in Equation 1) $X_j$ is expressed as follows:

$$X_j = \sum_{i=1}^{n} W_k W_{ki} a_{ij} \qquad (1)$$

-$W_k$ is the weighting of criterion k

-$W_{ki}$ is the weighting of the $i^{th}$ sub-criterion in the category of criterion k

-$a_{ij}$ is the importance level of $j^{th}$ alternative with respect to the $i^{th}$ sub criterion and kth criterion.

Table 4 presents the developed comparison matrix for the criteria identified for fabric selection.

Vector of priorities (the Eigen vector of the developed matrix) addressing the weight of criteria has been identified and presented in Equation (2):

$$\text{VOP}=\begin{bmatrix} 0.1376 \\ 0.4581 \\ 0.2627 \\ 0.0453 \\ 0.0663 \\ 0.0299 \end{bmatrix} = \begin{bmatrix} \text{Durability} \\ \text{Cost} \\ \text{Permeability} \\ \text{Sewability} \\ \text{Tesnsile Strength} \\ \text{Aesthetic} \end{bmatrix} \qquad (2)$$

Since the decision makers may be unable to deliver perfectly consistent pairwise comparisons, it is demanded that the comparison matrix should have an adequate consistency, which can be checked by the following consistency ratio (CR):

$$\text{CR}= \frac{(\lambda max - n)/(n-1)}{RI} \qquad (3)$$

where, $\lambda_{max}$ = 9.73(0.1376) + 1.9(0.4581) + 4.79(0.2627) + 25.33(0.0453) + 16.83(0.0663) + 29(0.0299) = 6.59

In calculating $\lambda_{max}$, the values in front of brackets are the summations in AHP matrix in Table 4, and the values inside the brackets are the corresponding VOPs. Random inconsistency index (RI) for 6 criteria is extracted from Table 3 provided by Saaty (2004) [27]. The Consistency Ratio (CR) has been calculated based on Equation 3. Since the value of CR is less than 0.1, it can be concluded that the accomplished judgement has consistency.

$$\text{CR}= \frac{(\lambda max - n)/(n-1)}{RI} = 0.095 < 0.1$$

Then the experts were asked to compare the main alternatives with respect to each criterion. Finally, global priorities of the different major options were estimated by multiplying the weightings of the alternative associated with each constraint by the criterion weighting and finding the overall sum. As shown in Table 5, ‘Barrateen’ has got the highest score in this analysis; hence it has been selected as the most suitable fabric for pneumatic formwork.

Table 4 AHP Matrix- Pairwise comparison of Criteria

| | Cost | Permeability | Strength | Sewability | Durability | Aesthetic |
|---|---|---|---|---|---|---|
| Cost | 1 | 1/5 | 1/3 | 5 | 3 | 5 |
| Permeability | 5 | 1 | 3 | 9 | 7 | 9 |
| Strength | 3 | 1/3 | 1 | 7 | 5 | 9 |
| Sewability | 1/5 | 1/9 | 1/7 | 1 | 1/3 | 3 |
| Durability | 1/3 | 1/7 | 1/5 | 3 | 1 | 2 |
| Aesthetic | 15 | 1/9 | 1/9 | 1/3 | 1/2 | 1 |

Table 5 Fabric Selection using AHP method

| | | Alternatives | | | | | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | | Rubber fabric (3mm) | | Vinyl Crystal 0.75 mm | | Herculon | | Lockram | | Laminated | Chamois | Hydrophobic | Polyester | Barrateen | |
| Criteria | Weight of the Criteria | Rating of the alternatives | Overal importance | Rating of the alternatives | Overal importance | Rating of the alternatives | Overal importance | Rating of the alternatives | Overal importance | Rating of the alternatives | Overal importance | Rating of the alternatives | Overal importance | Rating of the alternatives | Overal importance |
| Durability | 0.07 | 4 | 0.27 | 4 | 0.27 | 4 | 0.27 | 2 | 0.13 | 1 | 0.07 | 3 | 0.2 | 4 | 0.27 |
| Sewability | 0.05 | 1 | 0.05 | 2 | 0.09 | 3 | 0.14 | 5 | 0.23 | 6 | 0.27 | 7 | 0.32 | 4 | 0.18 |
| Permeability | 0.46 | 1 | 0.46 | 2 | 0.92 | 3 | 1.37 | 4 | 1.83 | 6 | 2.75 | 5 | 2.29 | 7 | 3.21 |
| Strength | 0.27 | 4 | 1.05 | 3 | 0.79 | 2 | 0.53 | 7 | 1.84 | 1 | 0.26 | 6 | 1.58 | 5 | 1.31 |
| Aesthetic | 0.03 | 1 | 0.03 | 3 | 0.09 | 5 | 0.15 | 2 | 0.06 | 7 | 0.21 | 4 | 0.12 | 6 | 0.18 |
| Cost | 0.1 | 1 | 0.14 | 2 | 0.28 | 7 | 0.96 | 4 | 0.55 | 5 | 0.69 | 3 | 0.41 | 6 | 0.83 |
| Total Score | | | 1.99 | | 2.4 | | 3.41 | | 4.64 | | 4.25 | | 4.92 | | 5.97 |

## 6. CONCLUSIONS

Innovations in formwork solutions and introduction of flexible fabric in place of stiff traditional formwork elements have created new possibilities for a wide range of construction components. Combined with textile formwork, the production of a new range of structural foam-filled panelized systems has become possible without intensive labour for traditional formwork installation. The objective of this study was to select the most appropriate fabric for a pneumatic formwork, which will be used for the newly developed structural foam-filled panels. First, based on the results of a survey, six criteria for a suitable pneumatic fabric formwork were selected such as permeability, strength, relative cost, durability, sew-ability, and aesthetics. Some experimental tests were conducted to determine the selection indicators for the criteria like durability and strength for each candidate. Then, an analytical hierarchy process was employed for decision making on the best pneumatic formwork candidate for foam-filled structural composite panels. The model can be applied on any potential decision alternatives considering the identified constraints and the associated determined weightings.

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