Gap Analysis for the Potential Use of Lightweight Steel Construction in Cyprus

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Abstract

In North Cyprus while reinforced concrete structures are used ubiquitously, steel structures are used very rarely. However, steel construction has some advantages over concrete construction. In order to investigate the actual rate of usage of steel construction in N. Cyprus and the reason for using or not using it, a questionnaire was prepared. It was concluded from the questionnaire results that, the main reason for not using steel construction is lack of knowhow of relevant people (engineering/architects). The building regulation in N. Cyprus dictates constructing the buildings up to four or five storeys. Therefore, it is expected that, lightweight steel structures will be used more in future. A decision support system was developed by using Microsoft Visual C# which included almost all of the lightweight steel construction details required for Mediterranean climate conditions. It was aimed that; such a system will produce expert recommendations in the domain of lightweight steel construction and will contribute to the training of the novice engineers/architects in lightweight steel construction.

Keywords: Decision support system, construction industry. Lightweight steel construction. Steel applications on sit.

1. INTRODUCTION

Reinforced concrete (RC) is one of the most essential structural materials. The basic ingredients of concrete are cement, aggregates and water which are locally available in almost every country. This is why concrete and RC materials are used ubiquitously. However, in some countries obtaining aggregates from the nature results with complains of environmentalist organizations. Similarly, RC is being ubiquitously used in Turkey and N. Cyprus where both construction industries shows similar patterns [1] but N. Cyprus is a small country and the aggregate quarries are creating an unpleasant and unsightly landscape.

On the other hand, the cost of the land especially in the cities also went up and adding one or two-story more on the existing buildings became feasible. Adding one or two floors by using RC system on the existing RC buildings in many cases is not possible or feasible due to the earthquake regulations. So many people are looking for other structural systems. One of the solutions for this problem is to use steel as structural elements. Structural steel elements can more practically be used either to reinforce the existing concrete elements before adding the extra floors or lightweight steel structures can be used for extension of the buildings or both system can be used. Although currently lightweight steel construction (LSC) is not widely used in N. Cyprus, it is obvious that, LSC will be required.

LSC has some advantages over concrete construction. These advantages are high strength to weight ratio, high quality material readily available in various certified grades, shape and sizes, easy and fast construction on the site, easy for modification, repair and demolition, flexibility for architectural and aesthetic designs, high durability and environmental friendly [2]. If the construction details are carefully analyzed and applied on the site, LSC yields better heat and sound isolation, longer economical life and better quality of the product. This is why there is a trend in the world for using more steel in the construction sector [3].

In this research, quantitative and qualitative research techniques are used in depth to gather information about potential usage of LSC in N. Cyprus. In order to inspect the potential usage of LSC and collect data in the form of numbers and statistics, a quantitative research technique; comprehensive questionnaire has been prepared. After the potential usage of LSC is measured through the questionnaire, it was observed that LSC is very rarely used by contractors in N. Cyprus. The results of the questionnaire indicate that, the most important reasons for not using LSC were the lack of steel consideration to be one of

the design option, lack of skilled labors in LSC and lack of knowhow about advantages of LSC in the high seismic hazard regions. Therefore, it is proposed that, mitigating this problem will be achieved through developing a Decision support system (DSS) to contribute to the training of novice engineers/architects in the subject of LSC. The DSS was developed by using Microsoft Visual C #. It included almost all of the LSC details under Mediterranean climate conditions of N. Cyprus and Turkey. Although the research is localized to the N. Cyprus construction industry, the method being proposed can be applied in other Mediterranean countries construction industries and with some minor modifications in other construction industries.

2. COMPARISON OF LIGHTWEIGHT STEEL AND REINFORCED CONCRETE STRUCTURES

Selecting the type of structural frame to be utilised in construction has dominant act upon the value of the construction as the structural frame supplies both functionality and future flexibility. In addition, it is the structural frame that dictates the speed and overall building cost of the construction process. Moreover, selecting the type of structural frame is quite important as it comes together with many other components of the building affecting their specification and buildability.

There are various options of structural materials in the construction industry (CI) such as concrete, steel, timber, and masonry. Despite the fact that various options of structural frame materials are available mainly structural steel or RC is being utilized in constructions [4]. Choice of material to be used as structural frame is highly dependent on the type of building to be constructed and site-specification constraints [5].

RC is ubiquitously used as major construction material in the whole world. On the other hand, using structural steel frame as major construction material is also becoming popular. LSC has some advantages over concrete construction. The comparison of lightweight steel structures and RC structures is given below.

Construction duration and predictability: The duration of RC skeleton construction is three times larger than the lightweight steel structure construction. With the help of off-site prefabrication of lightweight steel framed structures, the speed, quality and the safety of construction is enhanced. In addition to these utilization of lightweight steel framed buildings rather than RC structures enhances the predictability of cost as well as the construction schedule. The amount of time saved by using lightweight steel framed structures rather than RC framed structures results with 2-3% of saving in terms of the overall building cost [6].

Weight of the structure: For a specific building, the dead weight of RC skeleton was obtained as 1450 ton, where the structure of the same building could be constructed by 718 ton of steel [6]. Proportionally decrease in building vertical seismic load and reduce cost of building foundation because of carrying less load are the most significant of lighter building [3].

Flexibility and adaptability: Due to the characteristics of lightweight steel elements, spacious rooms can be built. Long spanning structural steelwork system provides areas freed from columns where this situation enhances the flexibility of floor layout, architectural design and improves the functionality of the space. In addition to these steel partition walls which are light can easily be repositioned so that the structure can be adaptable according to the future needs. However, besides the fact that concrete elements are not future adaptable they are larger in size that results with loss of space. Furthermore, utilization of concrete elements does not allow having larger spans as steel elements do [6].

Sustainability: Steel is completely recyclable without losing its quality [7]. Nowadays in UK, buildings which have already been built steel framed and come to the end of their useful lives provide 86% of the steel section to be recycled in order to create more steel products and provide 13% of the steel section to be functioned in the existing form. Recycling rates for the reinforcement bars used in concrete framed structures are negligible compared to the recycling rates of steel used in steel framed structures [3]. In North America steel industry where over 80 million tons of steel were recycled in 2006 is the single largest recycler. Some countries report that their steel recycling is as high as 85% where in Canada this number was about 53% making an average of 8 million metric tons being recycled [7].

Construction: During the construction on the site, since the steel framing members are manufactured with pre–punched holes for running piping and electrical wiring, it will be minimizing preparation work for other trades. On the other hand, steel framing accommodates all types of commonly used finishing materials [3].

Delivering the materials: Compared to the ingredients of concrete such as; sand, aggregates, concrete (if pre-cast) and etc., delivering of steel materials to the site is relatively easy, especially light weight steel structures constituents require no heavy lifting mechanism for loading and unloading purposes [3].

Quality: All steel elements are produced, cut or bent in factory medium mostly controlled by means of computer. So, the quality of these elements is controlled better than the site produced concrete elements. The

levels and lines of factory produced steel elements are perfect. Some assembling of the elements is also performed in the factory medium. Therefore, the steel structure provides better quality than concrete structures [3].

3. E-TRAINING AND DECISION SUPPORT SYSTEM

E-training has been defined as "the delivery of a learning, training or education program by electronic means" [8]. E-training comprise the use of electronic equipment in some way to deliver training, educational or learning materials. Many researchers have proven that learners learn more using computer-based instruction compared to conventional methods of teaching [9-13]. The increased level of contribution through interactivity could be a reason for the effectiveness. This contributes to higher levels of cognitive engagement and retention. The self-paced nature of the learning experience also contributes to higher retention as the learning content is digested at the pace that adjusts the learner and not the pace at which it occurs to be delivered by the instructor. DSSs can be considered as a type of E-training system that present sufficient and necessary information for users and increase their knowledge. Thompson et al. have stated that DSSs can be used to decrease the needed time to make critical decisions and to guide long-term decisions such as training [14].

The DSSs are initially developed in the seventies and matured in the eighties [15]. These systems can be interpreted as an intelligent computer-based algorithm that simulates human decision-making skills [16]. In other words, DSSs reach the same conclusion that the human expert would reach if faced with a comparable problem [17]. DSSs use domain specific knowledge and heuristics to perform many of the functions of a human expert. The success of any DSS relies mainly on the ability to formalize and represent the knowledge within a discipline. Moreover, Arockiasamy has delineated DSS as a branch of artificial intelligence that deals specifically with automating and advice-giving capabilities of human experts [18]. There is also another interpretation that define DSS as a computer program that solves problems traditionally solved only by a human expert. It captures and manipulates knowledge and strategies that a human expert applies to solve a problem [19].

The most auspicious technique for developing DSSs is rule-based systems [19-21]. In comparison with traditional computer programs, the rule-based systems have a capability to deal with qualitatively problems [22]. The rule-based DSSs are created mostly using if-then statements instead of ordinary practical codes [23, 24]. DSSs have been increasingly identified as an effective method for solving various problems in the CI [3, 24-28].

4. METHODOLOGY

In this research, quantitative and qualitative research techniques used to gather information about potential usage of LSC in N. Cyprus into depth. In order to inspect the potential usage of LSC and collect data in the form of numbers and statistics, a quantitative research technique; comprehensive questionnaire has been prepared. After that, by qualitative research methods such as; interviews with experts of domain and site visits, particularly required knowledge acquisition has been undertaken which was used to prepare a strong database. This is done with the intention of enhancing the level of knowhow up to an adequate stage about LSC. In the next step, a decision support system has been developed in order to enhance the engineering staff about the site application details of lightweight steel construction using Microsoft Visual C#. Finally, in order to validate the designed decision support system, number of experts have been requested to test the program and evaluate the results. Figure 1 illustrate the methodology process of this study.

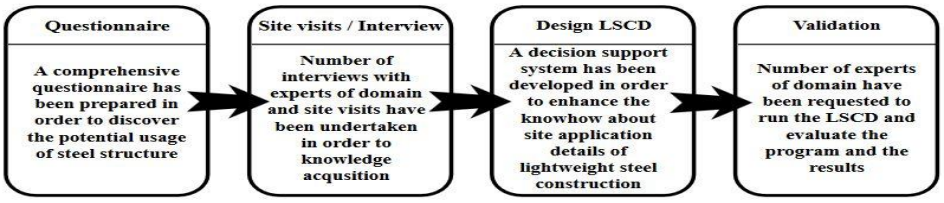

Figure 1. Research methodology process

5. QUESTIONNAIRE SURVEY

A questionnaire was prepared and targeted 150 number of registered active contractor companies in Cyprus Turkish Contractors Association (CTCA) to collect professional data in order to identify how often the contractors in N. Cyprus are using lightweight steel construction and discover the main reason for using or not using steel construction. It was believed that preparing a questionnaire would be the most suitable method to gather practical information from contractors for an academic research. All the collected data with help of questionnaire were analyzed with the Statistical Package for the Social Science (SPSS). The questionnaire survey respond rate of 28% (42 of 150) was considered acceptable in comparison with the response rate of most questionnaire surveys in the CI [29, 30].

According to the bylaws in N. Cyprus there are five types of contractorship licenses such as; Type 1, Type 2, Type 3, Type 4 and Type 5. These licenses are given to the contractors according to their company's fleet of construction equipment and machines, area of construction completed in square meters, employed number of architects/engineers etc. The largest contractors are in Type 1 and the smallest contractors are in Type 5.

As it can be seen from Table 1, among the participant contractor firms, the largest group is the Type 1 contractors with a rate of 47.6%, Type 2 contractors take in the third level with rate of 26.2% after Type 3 contractors with rate of 26.2% and the smallest group is Type 4 and Type 5, relatively with a rate of 4.8%.

Table 1- Type of contractorship license held by the participant contractors

Contractorship licence type	Number of contractor firms	Percentage of contractor firms
Type 1	20	47.6
Type 2	7	16.7
Type 3	11	26.2
Type 4	2	4.8
Type 5	2	4.8
Total	42	100

Figure 2 illustrates number of engineers/architects working in the firms and the range of area of construction completed by those firms since their establishment with respect to firms' contractorship license in terms of percentage.

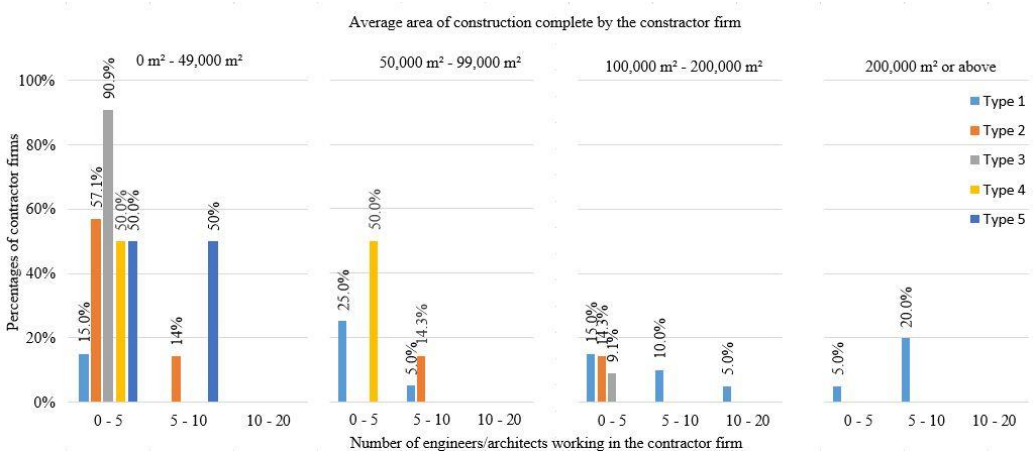

Figure 2. Employee numbers of contractors and average area of construction completed by participant contractors

Figure 3 illustrates the type of construction and the materials used in the structural construction according to the type of contractorship licenses. The two main types of construction in N. Cyprus are residential and commercial buildings construction. Only steel and RC are used as structural material in building construction in N. Cyprus.

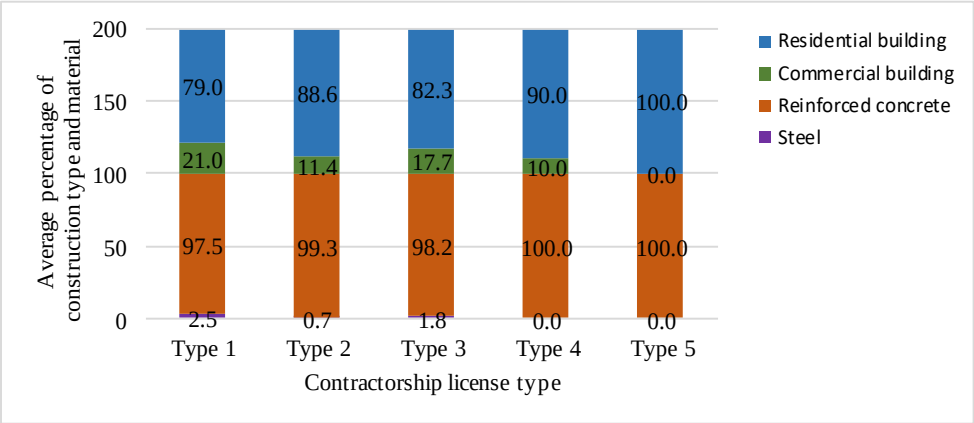

Figure 3. Construction types and materials used by the participants

With regard to this fact that steel is not produced in N. Cyprus and therefore all of the steel used in construction sector is imported, source of construction materials and construction workers are shown in Figure 4 below.

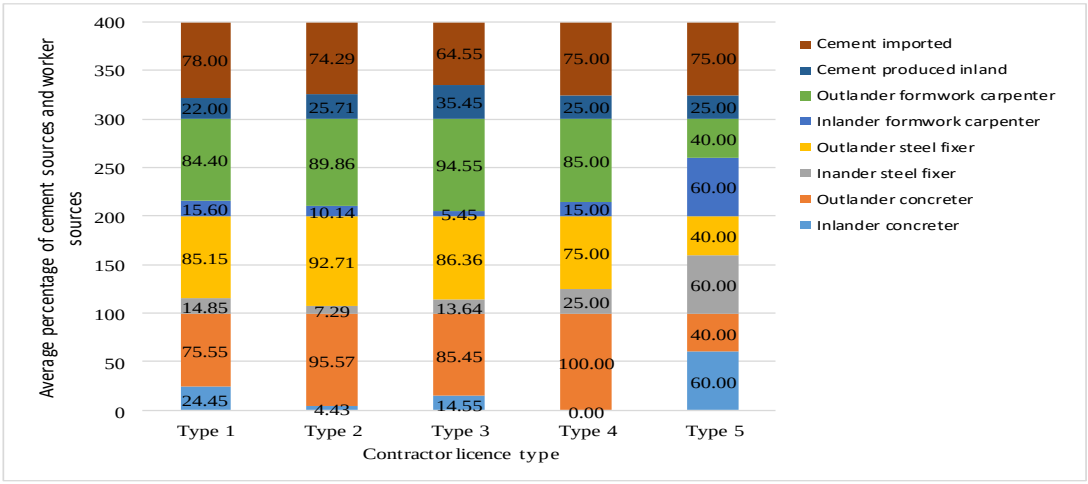

Figure 4. Sources of cement and construction workers.

The questionnaire demands from the participants to create a priority list as an answer of the reasons for not using steel construction in N. Cyprus. The correspondent contractors stated that, two of the most important reasons for not using steel construction in N. Cyprus are; “Lack of steel consideration to be one of the design option” (19%) and “Lack of skilled labors in steel construction” (16.2%) where these reasons are depending on lack of knowhow holding 35.2% of the whole reasons. “Lack of knowledge about advantages of steel construction in high seismic hazard regions” and “Steel construction’s initial cost is more expensive compared to RC” are the other reasons depending to lack of knowhow, which hold 25.4% of the whole reasons. The remaining 39.4% of the reasons for not using steel construction in N. Cyprus depend on the lack of availability of steel materials in the island.

The questionnaire also demands from the participants to create a priority list for the reasons that the people prefer using steel construction. From the result, it can be seen that, two of the most important reasons for using steel construction are; “Having shorter construction time compared to RC” (23.5%) and “Providing more flexibility compared to RC” (18.9%) where these reasons indicate the distinctive advantages of steel structure over RC structures. “Steel construction being cheaper in terms of life cycle cost compared to RC”

and "steel construction's positive effects on sustainable environments" are the two reasons by 11.4% and 11.9% respectively which are the lowest principles taken into consideration.

When the construction sector in Cyprus is analyzed, it is understood that about 88% of the constructions are residential type buildings and the remaining 12% is commercial type developments. The main structural material of 99% of these constructions is RC and only 1% of them use steel as the main structural material. This shows that steel construction is almost not applied at all in the CI in N. Cyprus.

It is clearly observed from the survey that in N. Cyprus there is no production of steel or reinforcement steel. The basic material produced in the island and used in RC construction is the cement. In fact, only 28% of constructions use inland produced cement as 72% of cement is imported. This indicates that, lack of readily available steel material in N. Cyprus will not cause any big problem in the application of steel construction since already importing of cement at a great rate does not create serious problems. Although 24% of participants mentioned that, the most important reason for them not using steel construction is due to the shortage of materials and probable delays in delivery times of these materials, these figures prove that, it cannot be a real problem for not using steel construction. If there would be any problem such as delayed delivery and shortage of steel material, the same problem would also apply to 72% of the cement or the entire reinforcement steel which are imported.

On the other hand, construction workers such as; 80% of the formwork carpenters, 75% of the steel fixers as well as 80% of the concreters are outlanders. Contractors mentioned previously that 16.2% of the reason for not using steel construction is due to lack of skilled labors. However, in the same way that they find and employ outlanders for concreting works, erecting formworks and fixing reinforcement steel, they can employ the skilled labors in steel construction as well.

As mentioned above, a good population of active contractors in building construction in N. Cyprus was visited and interviewed. At the end of this questionnaire it was understood that every participating contractor employs at least several engineers/architects. The major construction materials and skilled labors already have been imported without causing serious problems. All of these data show us that, the only considerable reason for contractors not to use steel construction is the diffidence resulting from lack of knowhow which promotes de-motivation. As it was declared by 45% of the participants, lack of knowhow is the most important reason for not using steel construction.

This problem is targeted to be mitigated by improving the knowledge of relevant engineers/architects in the sector. In order to manage this, it is believed that developing the DSS to provide expertise information in steel construction area will contribute to more usage of steel construction in N. Cyprus. The DSS can be used by engineers/architects whenever and wherever the knowledge is needed. Besides, such a tool can also be used to train the novice engineers/architects and other relevant staff of the contractors in the CI.

6. DECISION SUPPORT SYSTEM DESIGN

It was hypothesized that, one of the most important reason for not using steel construction in CI in N. Cyprus is the lack of knowhow of engineers/architects. By analyzing the results of the questionnaire, it was concluded that the hypothesis about the main reason for not using steel construction in the island is correct. In order to mitigate this problem in N. Cyprus, a DSS in the area of lightweight steel construction was developed.

Lightweight steel construction procedures can be grouped in three phases. First phase is the architectural and structural designing of the building. Second phase include the production of lightweight steel elements in the factory. In this phase, steel elements are cold rolled, cut, bent, coded and packed to be sent to the construction site. Some elements, like panels, are also assembled in the factory. In the third phase, the elements are unpacked on the site and the building is constructed.

The most important factor in steel construction is erecting the structural elements flawlessly on the construction site. This research covers the procedures to be done on the construction site. During the third phase of the lightweight steel construction, great attention is to be paid for the points below.

- Perfect waterproofing: Mistakes in waterproofing will result in corrosion of the lightweight steel elements.
- Fire resistance: Lightweight steel elements are sensible to fire. Therefore, great attention is required for fire insulation.
- Heat isolation: Lightweight steel construction has the capacity to provide the heat isolation at the required rate during both the assembling of the panels in the factory and erecting the steel beams, trusses and columns on the construction site.

- Sound isolation: Lightweight steel construction has the capacity to control propagation of the sound. The soundproofing capacity of steel structures can be controlled by the acoustic characteristics of internal wall and ceiling materials, and fixing proper sound shock absorbers inside of the steel slab. Therefore, great care is to be paid on the construction site to provide the required sound isolation.

It is obvious that, as explained above, the details of lightweight steel construction during the erection of the building is paramount. Mistakes during the third phase of steel construction can destroy the advantages of lightweight steel construction. The application details of lightweight steel construction require high expertise in the domain. Therefore, to enhance the knowhow of engineering staffs about the site application details of lightweight steel construction a DSS, called Lightweight Steel Construction Details (LSCD) was developed using Microsoft Visual C# 4.0. The concept of LSCD is illustrated in Figure 5.

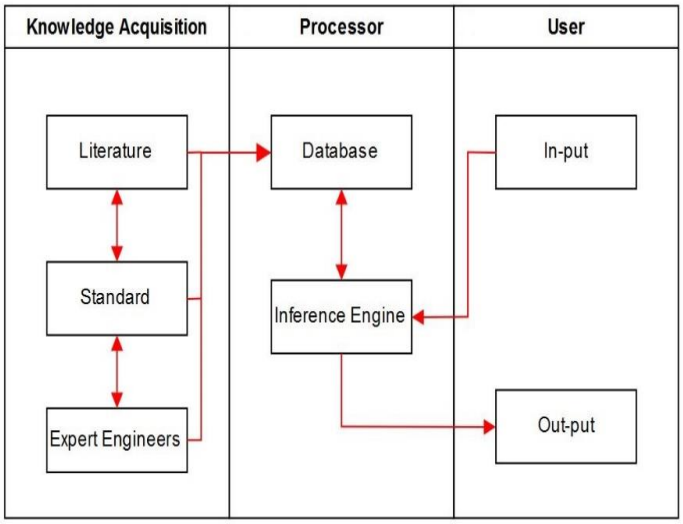

Figure 5. The concept of LSCD

7. DEVELOPMENT PROCESS OF LSCD

The LSCD system has been developed for windows based operating systems only by using .net framework 4.0 visual libraries. The layout of the program is designed to be user friendly. Having started LSCD, a number of different windows will come up. The windows come one after the other one sequentially. The answers of user for each question provided by the program is held in a list of objects data type, so that according to the user's answers, the program drives by putting a figure on the screen providing necessary information for the user. LSCD covers recommendations on lightweight steel construction in the following subjects.

- Foundation-steel columns connections of the building
- Details of inclined roof with inclined ceiling
- Details of inclined roof with flat ceiling
- Details of flat roof construction
- Details of roof trusses
- Details of wall panels

The questions that are expected to be answered by the user are depicted below in the flow of the program (Figure 6). With regard to the answer of each question, a figure with appropriate detail will be shown to the user.

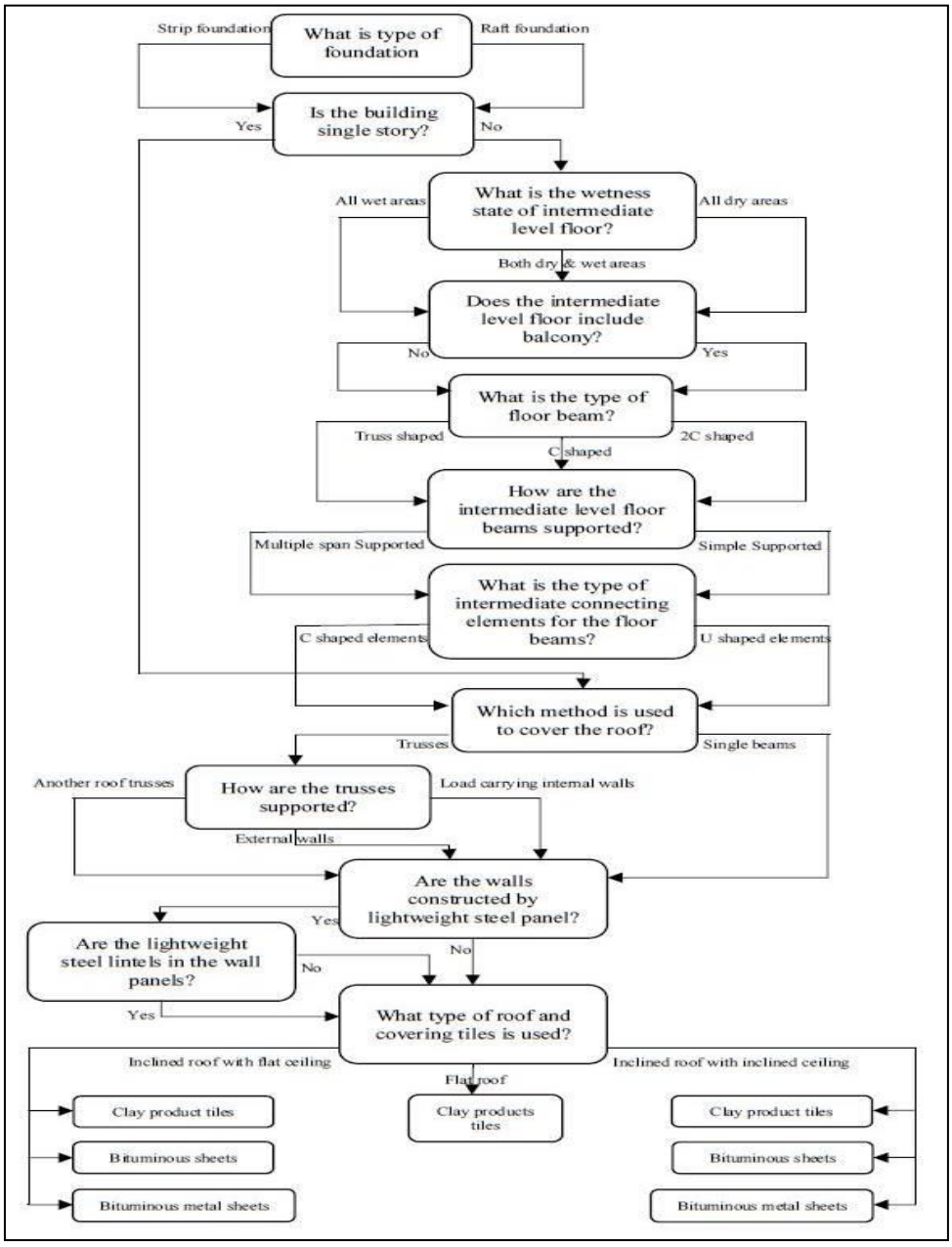

Figure 6. The LSCD flowchart

8. VALIDATION PROCESS

Unlike many conventional computer programs, DSSs do not solve problems which can be assessed by clear answers like “yes/right” or “no/wrong”. After the LSCD system is developed, it was run by number of domain experts, who are civil engineers and/or managers of firms that hold Type 1 contractorship license, to test and evaluate LSCD. During the evaluation of the system adequacy of the knowledge representation, consistency of the embedded knowledge with the experts, and the ease of interaction of the system with the user were checked. At the end of the evaluation, the ability of the system to perform the required task is analysed. If the system performed the task satisfactorily according to the tester, it was accepted as useful. So, evaluation can be defined as measuring the degree of success of a DSS of an expert in performing a required task. The evaluators have proven that the LSCD illustrates sufficient details of lightweight steel construction assembling techniques and application of lightweight steel structures on the site. They also stated that the

program is very user-friendly and can provide essential, sufficient and useful knowledge about lightweight steel construction to novice engineers/architects in a few minutes after answering questions compared to traditional methods that take long time to investigate them. In addition, the evaluators suggested that it would be better if the LSCD program can provide more explanations in words on technical details to be more useful for workers and foremen.

9. CONCLUSIONS

Nowadays, RC construction is the dominant method of construction in the N. Cyprus young construction sector whereas steel construction is very rarely used.

The results of the questionnaire organised among the contractors in N. Cyprus showed that, the main reason for not using steel construction is the lack of knowhow in engineers/architect and labours. Lack of knowledge about steel construction breaks their confidence in considering the steel construction method.

With a recently change in building regulations in N. Cyprus, it became feasible to construct up to 4 or 5 storey buildings where previously 3 storey buildings were more feasible. Therefore, it is expected that steel construction - but especially lightweight steel construction - will be used widely in the near future.

In order to enhance the knowledge about lightweight steel construction site application methods, and to train novice engineers/architects and labours, it was decided to come up with a DSS in the domain of lightweight steel construction. In the knowledge acquisition stage of the system, literature review, construction site visits, cold rolled lightweight steel elements production factory visit, and interviewing of domain experts were undertaken. Lightweight Steel Construction Details (LSCD) was developed aiming to provide expertise recommendations in this domain and to train people relevant lightweight steel construction works.

The LSCD program was evaluated by number of domain experts to measure the efficiency of the system. All of the evaluators found the system useful, user-friendly and quick to produce expertise solutions. The efficiency of the system was also appreciated. However, evaluators suggested that providing more explanations in words on technical details would increase the LSCD benefits for site personnel such as workers and foremen. It is accepted that this criticism is to be considered as further improvement of the system. In addition, the LSCD provides expertise recommendations on lightweight steel construction details for regions under Mediterranean climate conditions. The contents of the system are recommended to be broadened by including the lightweight steel construction details for the remaining climate regions as well.

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