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The Elimination of Problems That Arise During The Construction Stage of Industrialised Lightweight Steel Residences

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Abstract: In this study, the main problems encountered during the production of lightweight steel systems are divided into two groups and analyzed. The first group includes problems arising due to material wastes in the production phase, inaccurate application of procedures by workers, shortcomings of the machines, lack of training, organization failure, delivery problems, inadequate protection of materials, etc. The second group covers issues such as heat insulation affecting usage of the structure, fire, sound, acoustic, corrosion problems, fire resistance, water tightness, etc. It is shown that productivity is raised where the difficulties of production steps are eliminated and production is simplified. Surveys should be conducted to develop controlled work flows and methods which can be applied continuously.

Key words: Lightweight steel · Residence · Constructional problems

INTRODUCTION

Because prefabricated lightweight steel-frame residences are made with products whose manufacturing process is finished within the factory, the manufacturing phase of these residences is faster than it is for those made with traditional systems [1, 2, 3]. The definition of industrialized housing is "Production in a closed environment where only assembly is performed at the construction site, with one evident process owner and a clear product goal of repetition in housing design and production" [4, 5].

The objectives of this project focusing on lightweight steel-frame residences are as follows:

- Increased design and production flexibility, an expansion of scope and the type of building solutions presented by the regulations and modular residence producers and an increase of production efficiency in a cost-effective manner.
- The manufacture and construction of residences with zero faults.
- The identification of the time periods of processes with the goal of eliminating overall waste including building materials and unnecessary workforce.
- Protect building from physical problems.

In recent years, very few changes have been seen in production methods in contrast to the expansion of the residential construction industry; studies focused on the management of this process, material storage and delivery methods are not sufficient.

A set of studies should be undertaken to increase productivity of industrialized lightweight steel structures. One result of the concern to optimize individual task execution is the recommendation that tasks with different characteristics be buffered from each other. While this approach has many advantages, particularly associated with the development of sophisticated production technologies, it also suffers some significant disadvantages such as the rising costs of work in-progress created by the buffers, the risk of sub-optimization at the system level and inflexibility in response to changing market demands [1, 6, 7]. Researchers have used information technology to advance in different areas. Information technology has been used in planning and control but also in design, knowledge discovery and management and production system design. In manufacturing many components from different sub-assemblies can be easily managed because

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suppliers are selected early in the design phase. Specialized facilities with suitable technology and layout ensure the reliable flow of the product. With repetition, this supply network eventually becomes manageable and optimised [1, 8].

Production is a flow of material and/or information from raw material to the end product. In this flow, the material is processed, it is inspected, it is waiting, or it is moving. These activities are inherently different.

The organization of light steel residences management efforts are still centred on task management and based on principles of the transformation concept. However, task management is not implemented systematically across all phases, resulting in added variability. Even where there is an intention to implement systematic task management, it corrupts, due to the high level of variability inherent to unsystematic management. There are two counterproductive results. First, unfavourable design of the production system emerges, where interdependent issues are managed by a fragmented and myopic organization. Secondly, bad control across all phases results [9, 10].

Work flow in the production phase is one area where energy efficiency and time saving can be achieved. Problems encountered during construction of lightweight frame structures mainly emerge during the design stage due to delivery, production of material and organization of construction site and during the assembly stage due to inaccurate and missing design/organization. As a result, problems due to material waste, time loss, insufficient performance of workers and so forth have a considerable negative impact on the budget of the project. For example, significant delay in the completion of the work may be encountered.

These problems can only be eliminated by selection of the most appropriate solution proposed after failures have been accurately identified. While efficiency is increased, other major objectives are design and production flexibility, production of materials with "zero" fault and decrease of wastes/scraps. In addition, production process of these structures constructed with standard elements should be staffed in a planned manner, efficiency should be increased in material storage stage and in the delivery methods and construction management phases. At each point, material and time loss may be eliminated by means of remedial studies.

MATERIALS AND METHODS

The quality of industrialised products differs with respect to the companies and the relationships between them [4]. The most significant part of the industrialised system is the utilisation of elements at different levels of standardisation and in different technical systems [11, 12, 13]. Standardised technical systems are prefabricated structural parts and systems that are assembled at the construction site. The sections where modular structural parts are available are brought together at the construction site after the completion of a complex manufacturing process [14, 15, 16]. The bearing elements of residences that use lightweight steel systems are shaped perfectly using computer-supported special machines. The prefabrication level of the structure changes depending on the components of the project. The construction proceedings at the site are minimised accordingly. The work to be undertaken at the site is minimised by providing a completion level of 60% using the panel system and 85% using the modular system. In particular, a completion level of 95% is achieved at the module systems due to the pre-completion of the installation systems and furniture (Table 1) [15, 16, 17].

Industrialised building construction is a construction system that is based on integration and the special mass production of systems (Table 1). In fact, the manufacture of modular system residences has similar features to car manufacturing. The final products are arranged to create a unique product with the components and parts taken from the platform. Because the products are made at the platform with common characteristics, their quality and reliability is extremely high. Therefore, this system is economic because there is an efficient distribution of the resources consumed for development from the initial platform into many products. Because the platform is developed and tested, the quality and reliability of the platform content is high [18]. The product development process requires a product team who are dedicated to this type of work, with competency in many areas such as project management, manufacturing, supply chains, market knowledge, continuous collaboration and the ability to focus on unique projects.

Two development lines are identified for the residential construction industry; one line is the development of available products and modules that comply with the technical platform and the other line is the development of new modules and components that can be integrated with the platform [19, 20]. For this process, customised production for a single customer is initiated based on the technical platform and module integration and responsibility for development, design, supply and assembly is assumed [21]. There is a range of standard houses that can be customised, to some extent, to meet the individual consumer choices. For production,

Table 1: Industrialisation levels of structures [22]

Type of building	Level of Prefabrication (%)
Rationalised housing	25-30
Industrialised building site processes	20-30
Standard ready-built	40-60
Ready built housing	50-80
Modular units/sanitary blocks	60-90
Mobile modular units	95-100
Automobiles	100

the designs are based on modules of transportable size. The materials are processes and sub-assemblies that are manufactured in the factories and brought to the assembly lines to produce the modules [23, 24]. Lightweight steel framing is an integral part of modular construction because it is strong, durable and lightweight with stable dimensions [25]. The most distinct difference between the general performance characteristics of modular construction systems and other construction systems are as follows:

- The size of the module elements requires cranes for lifting and installation purposes.
- The flooring and walls should be separated and a certain level of insulation should be maintained to enable fire safety. Insulation between the modules prevents the rapid dissemination of fire from any one part to another.
- Different roof types may be produced.
- The installation of services is easy. Generally, services are installed within the production facilities, as a result of which this process is eliminated in the construction sites.
- Easy maintenance; in particular, the maintenance of services is easy.

Standardisation means that problems are eliminated by using systematic rules to deliver the optimum technical and economic solutions. Standardisation is based on the utilisation of elements with standard dimensions. Modularisation occurs when a structural system is divided into standard elements. It is relatively simple to combine modules with the same dimensions in terms of overall mass; openings in the façade of the module are also important for horizontal expandability. The standardisation of construction methods allows for the completion of a construction project within the shortest possible time period [26, 27, 28].

An optimum analysis of lightweight steel residence systems is applied using modular coordination principles. The basic dimension of any geometric classification system is called a module. The dimension unit of this module is a technical size defined as the module (M). The general basic module unit is M: 100 mm in Europe. The dimensions for M follows the German DIN 18000 standard; 3M=300 mm, 6M=600 mm, 12M=1200 mm. With respect to the module selected, the grid is a geometrical system that identifies the location and dimension of the modular construction elements. The grid may be derived from a square or a rectangular unit [13]. This grid can be used in the establishment of a structural system or it can be used in the placement of the installation systems that must pass between the suspended ceiling or walls [14, 29, 30].

The actions required during the design and production stage to enable production efficiency in lightweight frame structures are separated into sub-stages and accordingly, objectives are identified below (Table 2a and Table 2b).

To develop industrialised residential construction, construction companies and other participants should use a common process structure that is based on this concept. The construction stages at the pre-assembly factory and the construction sites can be used to enable uninterrupted processes and increase the efficiency of the system [31, 32]. During the pre-assembly stage, the use of materials, the conditions related to the workers, the supply of materials, the material supply models and the technical solutions (including the processes within the factory and purchasing) should be arranged in a systematic order to avoid affecting the work flow [33]. Based on past experience, the results of the project should be analysed for future projects. Because the overall experience of employees is extremely important, they should be provided with preliminary training on the scope of the processes. One of the main advantages of industrial pre-production is the ability to provide a quality warranty for the construction elements produced. Regardless of the weather conditions, it is possible to enable continuous quality control within the production facilities. For the production of larger units, an automatised production band is required [34, 35].

Problems of the Production Facility and Assembly and Solution Suggestions

Production Stage: Production is a flow of material and/or information from raw material to the end product. In this flow, the material is processed it is inspected, it is waiting or it is moving. These activities are inherently different. Processing represents the conventional aspect of production; inspecting, moving and waiting represent

Table 2a: Criteria to achieve production efficiency in lightweight steel structures [36, 37, 38, 7, 9]

Main Stage	Sub-stage	Aims
Design Stage	Design Stage	• Standardizing parts, materials, tools etc.
	Leadership	• Leaders develop and communicate mission, vision and values
		•Leaders are actively involved in ensuring managemenet systems are develped, implemented and contuniously improved
		• Leaders measure organizational performance and translate results into improvements
		• Leaders are actively involved customers
		• Leaders are actively involved with stakholders
		• Leaders create an environement for emppowerment, innovation, learng and support
	Stakeholder Focus	• **Customer focus
		• Systematic identification and monitoring of customer requiremenets and deeds
		• Translation of customer reguirements and needs into actions and expressed in company's product/services.
		• Organization staff are actively involved with customers
		• **Other stakeholder focus
		• Systematic identification and monitoring of stakeholder requirements and needs.
		• Translation of stacholder requirements and needs into actions and expressed in company's prdouct/services
		• Organization staff are actively involved with stakeholders
	People Management	• People resources and capabilities are planed, managed and improved
		• A heathy and safe work environment exist
		• Worker are motivated
		• Teamwork is encouraged
		• Time loss of workers in terms of working period and accordingly, economic loss due to non-definition of tasks of the workers in timely manner
	Protection of Building	• Heat isolastion
	Phiysics Problems	• Fire Isolation
	(See Table 4)	• Acustic Isolation
		• Prevention of condensation and water leakage
		• Prevention of heat bridge impacts

Table 2b: Criteria to achieve production efficiency in lightweight steel structures [36, 37, 38, 7, 9]

Main Sta.	Sub-stage	Aims
Production Stage	Increase Output Value	• Work schedule should be strictly complied for completion of works in timely manner.
		• Employye moviation
		• Response defects
		• Team work should be realized.
		• Team chiefs should be well-aware of works and well-manage their team
		• Regular maintenance and repair of tools
		• Continuity of work flow
		• Benchmarking
		• Eliminating work-in-progress
		• Reducing batch sizes
		• Changing plant layout so that moving distances are minimized
		• Keeping things moving; smoothing and synchronizing the flours
		• Reducing variability
		• Changing activities from sequential order to paralel order
		• Isolating the main value –adding sequence from supportwork
		• In general, solving the control
	Reduce Processes Variability	• Customer point of view a uniform product is better [39, 29].
		• Variability of activity duration, increases the valume of non- value-adding activities.
		• Reducing the part count of products through design changes or prefabricated parts
	Continuous Production	• Continuous material flows
	Flowing	• Continuous location flow
		• Continuous assembly flow
		• Continuous material and/or information from raw material to the end product.
		• Workers must not wait for moving and waiting product.

Table 2b: Continued

	• For material flows, processing activities are alternations up shape or substance, assembly and disassembly.
Supervision with Information	• Decrease of production failures to "zero"
Communication Systems	• Simplification of work flow continuously
Increase Process Transparency	• Establishing basic housekeeping to eliminate clutter:
	• Making the process directly observable through appropriate layout and signage
	• Rendering invisible attributes of the process visible through measurements
	• Embodying process information in work areas, tools, containers, materials and information systems
	• Utilizing visual controls to enable any person to recognize standards and deviation
	• Reducing the interdependence of production units
Centralized Control	• A further important principle is centralized control.
	• Management efforts are still centred on task management and based on principles of the transformation concept.
	• Unfavourable design of the production system emerges, where interdependent issues are managed by a fragmented and myopic organization.
	• Bad control across all phases results [36].
	• Minimising the amount of control information needed
Benchmarking	• Knowing the process; assessing the strengths and weaknesses of sub processes
	• Knowing the industry leaders of competitors; finding understanding and comparing the best practices [40].
	• Incorporating the best; copying, modifying or incorporating the best practices
Assembly Phase	• Shortening the flows by consolidating activities
	• Decoupling linkages

the flow aspect of production. Flow process can be characterised by time, cost and value. Value refers to the fulfilment of customer requirements. In most cases, only processing activities are value-adding activities. For materials flows, processing activities are alternations of shape or substance, assembly and disassembly [36].

The Arrangement of The Production Facility: Workplace organisation encompasses the degree to which the job site material, equipment, tools and resources are organised and structured for efficient project execution. Each practitioner should label and/or otherwise mark the production location and analyse the production facilities. The work to be completed should be arranged near the production bands [41, 42]. Unnecessary materials should be eliminated from the work area and necessary items, such as electric drills, nails, etc., should be placed in easy-to-access areas. Labels attached to the products should indicate the section of the residence where the related product will be used. Practitioners should regularly audit their control list and evaluate their equipment [43].

Material Storage: For a continuous work flow, the quantity of materials should be controlled at the stations. If the materials run out at a station, the activities will be interrupted. To obtain new materials, a visit to the warehouse would be required, which loses time. When the quantity of materials decreases, a signal should be given to the authorised personnel and the necessary material should be supplied.

The Utilisation of Appropriate Devices for Each Process: The selection of the correct materials is essential in terms of the efficiency of the production process. Electric drills should be used to install screws in lightweight steel systems. Implementing the use of electric drills will facilitate both screwing and removing screws.

Sophisticated Personnel Training: A multi-function team is a group of people working together to accomplish specific tasks; each team member may undertake and perform more than one task. Through this method, the dependence on any particular individual may be lessened, but this process requires personnel training [43]. Different functions are assigned to the teams, who are trained for many tasks, including material loading, discharging, purchasing, planning and control, maintenance and quality control. This extensive training eliminates the need for other teams [44]. Briefings are essential to enable teamwork with respect to the identified objectives. Information should be shared during the production flow and transferred directly to the team. The briefings are focused on the general performance of the company and the performance of the team [8, 45, 46].

Decentralized Distribution of Responsibilities: Responsibilities are distributed to the multi-function teams; responsibilities are not maintained at the centre and a master role is not needed because the tasks are implemented by the specially trained group members [44].

Simplify by Minimising the Number of Steps And Parts: Simplification can be understood as follows[15, 42]:

- Reducing of the number of components in a product
- Reducing of the number of steps in a material or information flow.

Practical approaches to simplification include the following:

- Shortening the flows by consolidating activities.
- Reducing the part count of products through design changes or prefabricated parts.
- Standardising parts, materials, tools, etc.
- Decoupling linkages.
- Minimising the amount of control information required.

Assembly Guide - Identification of Locations for Drilling Devices: Practitioners save time by identifying locations for the repeated elements and holes in a section. In the scope of any assembly guide, the elements and their related locations should be identified clearly. The construction processes or repeated assembly processes are marked within the assembly guide so that assembly efficiency is achieved. Skewing may occur during the installation of a ceiling under the flooring, for example, because of irregular placement profiles and this skewing should be identified using special measurement devices. Deflection may occur in some lightweight steel bearing elements. Precautions should be taken during the initial stages; otherwise, these issues may not be eliminated in the later stages of construction [42, 46].

Minimise Welding: Welding lightweight steel materials is difficult, as it deteriorates the galvanisation on the surface of these elements. However, many different methods are available to mitigate the amount of welding that is necessary. First, the welding processes for small parts that are necessary to shape long plane elements can be easily mitigated. Generally, screws are used in the assembly of lightweight steel structures and the screwing process allows for the easy dismounting and replacing of steel elements. Therefore, faulty combinations are corrected easily and this process is cleaner and faster than welding.

Minimise Waste: Lightweight steel systems are made by cutting elements into particular dimensions as stated in related projects. The dimensions should be measured carefully, the section to be cut should be marked and the cut should be applied following a control process because an addition cannot be made after cutting. Small parts are also used in other parts of the project. The material loss is kept to a minimum through these systems and the materials not used can be recycled.

Bossink and Brouwers [47] identified the 6 main sources of waste in construction as follows:

- Design
- Procurement
- Materials handling
- Operation
- Residual
- Other

Structural Physics Problems with Lightweight Steel Structures and Suggestions for Solutions (Table 4): Heat Insulation: The removal of the profiles on the walls, which are applied to decrease heat transfer, is also applicable in this section. To prevent or minimise heat transfer within lightweight steel structures, profiles are placed on the walls by means of disorientation. In this manner, the transfer of the heat through the wall body is minimised. In particular, the corners and the shell structure should be taken into consideration. The continuity of profiles should be prevented on these points [30]. Fibreglass insulation is implemented within the walls to provide heat insulation. If additional insulation is requested, it should also be added. Harder insulation is applied on roofs. Advanced steel posts should be used to prevent the formation of thermal bridges. The placement of steel posts in the wall panels is important. Hard insulation materials should also be used under the floor joists. Mineral wool plates should be placed continuously on the sides and surrounding air gaps in the walls.

Fire: Precautions against fire should be taken at the walls and the floors of lightweight steel structures. Fire resistance can be increased through the use of gypsum panels, mineral glass fibre gypsum panels, etc., on the floors. Organic-based insulation materials should not be used on the floors.

Acoustic Problems And Solution Suggestions: Acoustics are a significant issue for lightweight steel structures. Therefore, insulation material with the proper thickness should be applied between the profiles. Noise within the structure occurs and disseminates for the following reasons: strike, friction or installation. To prevent noise within the profiles and to enable the dampening of noise before its strike onto the profiles, sound absorbing flexible elements should be used. In some cases, twisted profiles are used to dampen sound and vibration. Double wall applications are much more effective than single wall applications in terms of the provision of sound impermeability. In addition, other solutions to this issue are the discontinuity of flooring and the implementation of wall coatings. The areas surrounding the installation materials should be covered with sound insulation materials. Flexible roving and gaskets placed onto the channels positioned on steel profiles prevent sound rising from a strike to the steel elements. To achieve proper sound insulation characteristics, the connections should be separated by means of soft, springy horizontal profiles that may be used as an addition or that can be separated completely. In addition, the profiles with perforated connection surfaces (flange) that are arranged to keep support (bed) surfaces at the minimum level are also available and may be used to decrease sound transfer. Filling 80% of the empty volume with fibre insulation material can also produce positive results in terms of an increase in sound insulation. The energy of sound waves is converted into heat energy while passing through fibres. Closed cell insulation materials, such as foam, are not appropriate for enabling sound absorption within empty cavities [48].

Acoustic Insulation of Floorings: The same precautions should be taken for the sound insulation of wall and flooring construction. The footstep level is essential in terms of the sound insulation of the flooring. While providing the related value in the footstep insulation of lightweight steel construction systems, the transfer of sound on the upper level of the flooring to the surface and the dissemination of sound within the underside of the flooring is prevented. The following factors are taken into consideration during the identification of footsteps on the ceiling [48]:

- Profile type
- Profile section
- Profile space
- Type and thickness of the floor coating
- Flooring type, thickness, number of layers and type of fixing
- Material type used to fill the empty volume of floor and the rate of filling
- The following preconditions should be met to apply burnt alum to increase the sound insulation level in the floorings of lightweight steel structures:
- Profile type
- Burnt alum plate > 20 mm thickness
- Bearing ceiling layer > 19 mm thickness
- Empty volume insulation, fullness level < 80%.
- Straps are separated from the springy rail, springy clips and any solid object that could cause sound transfer.
- Two-fold ceiling slab < 2 x 15 mm.

Acoustic Insulation of Walls: The following applications are important during the formation of connections to provide good acoustic insulation on the walls of lightweight steel structures.

- Adjacent structural parts should be separated from each other to provide acoustic insulation
- Any structural parts in contact with each other should be separated Connect using insulation strips and insulation materials
- Use special profiles where the insulation strip is attached
- Trowel and plaster the connection surfaces carefully to provide impermeable connections
- The elimination of the strike noise from the installation systems that occurs as a result of a strike to the bearing system should be provided by utilisation of flexible, plastic layered pipe clamps. The pipes should be insulated against band and wall construction using materials that perform a sound insulation function for the attached strip.

An overall fixed connection should be prevented between the sanitary system elements and the wall/ flooring members [49, 50]:

- Provide sound insulation for the installed elements, considering the construction of the basin and the bearing frame by using elastic intermediate layers.
- Insulate the washbasin and the washbasin foot by placing them onto the floating alum to provide sound insulation.
- Separate the washbasin and the washbasin slope from the walls using insulation stripes. Surround the sides of the washbasin with washbasin side profiles that have a sound insulation function.
- Provide sound insulation by fixing the sanitary system elements, such as the fixture connections, to the ceramic tiles and by using elastic intermediate layers or by fixing connection boxes made of synthetic material.

- Use special sound insulation pipes, particularly in sensitive areas; it should be taken into consideration that the outer diameter of sound insulated pipes is larger than their equivalents (to illustrate, for any sewer system pipe, it should be 120 mm instead of 100 mm).
- Prevent a connection between the potable water network and the waste water network
- Fill the remaining gaps within the installation walls and use sound absorbing insulation material.
- Wrap all pipeline with soft, flexible material
- Prefabricate the installation walls, wall-front installation systems or their elements to prevent any implementation failures that may occur during assembly at the working construction site; employ personnel who are well trained in sound insulation.

Prevention of Condensation And Water Leakage: Materials with low vapour permeability (vapour proof) should be used within the inner sides of lightweight steel structure walls and materials with high heat insulation characteristics should be used in the outer sides. With this method, condensation due to vapour within the inner section and cold heat at the outer side is prevented. With respect to the type of coating, vapour-proof materials may also be placed within the inner sides. Attention should be paid to providing uninterrupted vapour-proof insulation at the corner wall connections. To provide air flow within the wall sections, it is recommended that at least 4 cm space is left and that open air-conditioning holes are provided every 100-120 cm, with an approximate diameter of 10 mm [48].

Prevention of Heat Bridge Impacts: The space available between the lightweight steel profiles should be filled with insulation material to cover the overall surface and prevent heat bridges. To obtain the appropriate energy behaviour from the lightweight steel structure systems, not only should outer structural parts with high insulation values be used, but structural part connections should also be selected and implemented accurately. Heat bridges emerge at the corner and connection points and the structural section addition-connection places because the intermediate gateways of the structural parts have a high transfer capacity, causing leakages in the external coating (convection heat bridges). The impact of heat bridges is indirectly related to the U-value of the limiting structure parts. A multi-layer insulation and thermo-profile material is used on highly insulated external walls.

RESULT AND DISCUSSION

As lightweight steel residence construction system is an industrialized construction system. As such, regularity in construction sites, continuous material flow and quality control can be easily realized. Manufacturing companies design profiles constituting the bearing system of the structure by means of computer aided machines and may accordingly produce required sizes without any failure. These elements may be delivered to the construction site without any scrap or any damage to the elements when necessary precautions are taken. The structure can be completed exactly to plan with a well-trained and well-organized team (Table 3). However, these criteria can sometimes not be realized due to various specific reasons. The most common problems related with lightweight steel frame systems are identified and solution proposals are presented below (Table 4-5).

Accurate transfer of visual and written information is important to maintain continuity of work flow during the construction phase. Time is also consumed for the repair of broken or failed tools; therefore, auxiliary tools should be made available at hand to prevent any interruption. If the construction area is complex and disordered, work flows cannot be fast and continuous. Any irregularity affecting the concentration of the workers should be eliminated. Materials should be kept at their related places; otherwise, searching for tools and materials will cause lost time. Standards should be improved for processing; planning of tools and maintenance should be performed with respect to this standard to enable work quality.

As a result of interviews conducted with companies that manufacture lightweight steel structures and based on the above scoring, water insulation, heat bridges, sound insulation, fire problems, acoustic matters and corrosion resistance problems can all be resolved. Notably, however, to prevent vibration within the flooring, the implementation of table concrete that does not comply with the prefabricated structure is inevitable (Figure 1). This evaluation is also applicable in terms of the impacts of implementation decisions on construction stages of lightweight steel residence systems. The decisions regarding construction site arrangement, the storage of materials, the improvement of details to decrease welding, the utilisation of tools appropriate to each process, simplification by minimising the number of steps and parts and the arrangement of the assembly guide (Figure 2) can all be applied with respect to the

Table 3: Principles increasing the quality of lightweight steel systems

Characteristics	Explanation
Regular Production Site	• Organise products in order of use • Attach labels to materials boxes (screws, nails, etc.) to enable easy identification of materials • Use labels to provide information about the usage place of materials • Keep the control list in a visible location • Keep the assembly project in a visible location
Continuous Material Supply	• Supply materials quickly • Inform warehouse workers of the supply of materials to prevent any interruption in the work flow
Total Quality Control	• High quality products will be obtained when production is realised without any impact from the weather conditions • Workers are well-trained and experienced • Quality warranty is given to the finished product, which gives confidence to the user

Table 4: Main reasons of Material Waste and Solution Proposals

Cons. Stage	Problems	Solution Proposals
Design Stage	• Lack of adequate information about dimensions, type and design documents of materials	• Adequate information about dimensions, type and design documents of materials
	• Providing inaccurate information about dimensions and types of materials	• Providing accurate information about dimensions and types of materials
	• Wastes arisen due to the designs in the scope of which material dimensions are not considered.	• Material dimensions should be taken into consideration in design.
	• Requirement to keep communication with high number of experts	• Increasing number of experts
	• Repeating working obligation for changes in design and lack of information flow	• High rate of amendments should be prevented within designs
	• Delay in project due to corrected detailed drawings	
Production Stage	• High rate of phases in production	• Simplify by minimizing the number of steps and parts
	• High rate of elements used	• *Reducing the member of components in a product
	• Continuity of information flow interrupts concentration	• *Reducing the number of steps in a material of information flow
	• Usage of elements in different dimension extends construction period.	• Standardization of dimensions
	• Material wastes during delivery of materials to the construction site	• Delivery of materials to the construction site in packaged manner
	• When materials delivered do not meet project requirements, new materials are waited	• Delivery of required amount of materials
Delivery Stage	• Materials may be broken, lost and exposed to various deformations during their loading to the trucks and their discharging from trucks and their stowing within construction site and placement to their relevant places.	• Proper packaging, orderly loading to the truck, discharging by means of related means or by workers from trucks
	• Avoid unnecessary transport (double handling)	• Unnecessary deliveries should be prevented
	• Delays in delivery	• Fast delivery
Construction Sit Organization Stage	• Materials may be used unnecessarily, when materials are not controlled within construction site.	• Necessary amount of materials should be delivered
	• Delivery of materials to other places	• Destination and delivery time of materials should be well-known
	• Unnecessary occupancy by the materials due to early delivery of materials	• Early delivery should be performed, delivery should be made with respect to the work flow.
	• Deformations may occur on structural features of the material due to climatic conditions.	• Materials should be kept within closed areas.
	• Delivery of more than necessary materials to the construction site	• Material amount required during construction stage and documents should be made available to the construction site chief.
	• Occupation of unnecessary area	
Assemby Stage	• Selection of inaccurate construction method	• The most accurate method should be selected among those increasing work efficiency.
	• Disordered assembly of materials due to breakdown of assembly elements	• Availability of auxiliary assembly elements • Repair of assembly elements broken within short time period
	• Untrained production workers	• Training of workers
	• Selection of complex details	• Simplicity of attaching one part to another
	• High rate of different component details	• Standardization of details
	• Inaccurate performance of tasks by the workers	• Accurate performance of tasks by the workers

Table 5: Structural Physics Problems of Lightweight Steel Structures and Suggestions for Solutions

Criteria	Characteristics
Heat Insulation	• *Profiles should be disoriented
	• *The continuity of profiles on corners should be prevented
	• *Fiberglas insulation should be used in the walls to enable insulation
	• *Harder insulation should be used on roofs
	• *Hard insulation should be used on the underside of floor joists
	• *Mineral wool plates should be placed continuously around air gaps in the walls.
Fire Insulation	• *Gypsum panel, mineral glass fibre gypsum panel, etc., should be used in flooring
	• *Organic-based insulation materials should be used in flooring
Acoustic Insulation	• *To prevent noise, for the profiles use
	• *Sound absorbing flexible elements
	• *Twisted profiles
	• *Implement a double wall
	• *Enable the discontinuity of the flooring; wall coating materials should be applied in sections
	• *The installation elements should be surrounded by sound insulation materials
	• *Strike noise is prevented by the placement of flexible roving and seals onto the channels positioned on steel profiles
	• *Separate connections mean of soft, springy, horizontal profiles
	• *80% of the empty volume should be filled with fibre insulation material to improve sound insulation
Prevention of Condensation	• *Use materials with low vapour permeability within the inner sides of walls (vapour-proof)
And Water Leakage	• *Use materials with a high heat insulation feature at the outer sides of walls
	• *Vapour-proof material can also be placed within the inner sides in accordance with the characteristics of the coating
	• *The vapour-proof insulation should be uninterrupted at the corner walls
	• *At least 4 cm space should be left to enable air flow within the wall sections
	• *There should be air-conditioning holes with an approximate diameter of 10 mm opened every 100-120 cm
Prevention of Heat	• *The space between lightweight steel profiles should be filled with fibre insulation material
Bridge Impacts	• *The connections for the structural sections should be selected and applied accurately
	•*Use multi-layer insulation and thermo-profile material on the external walls

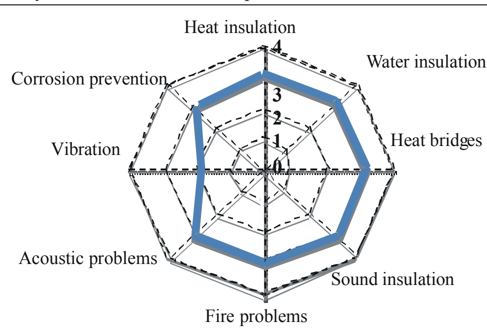

Fig. 1: Solutions to the structural physics problems 0. Irresolvable, 1. Very few solutions may be applied, 2. Few solutions may be applied, 3. Resolvable at a medium level, 4. Resolvable completely

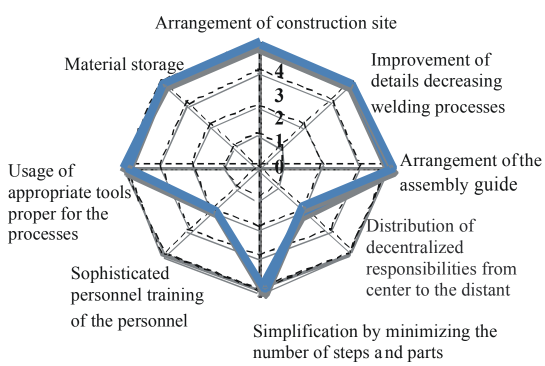

Fig. 2: Impact of decisions regarding the industrialised lightweight steel residence systems on the construction stages 0. Irresolvable, 1. Very few solutions may be applied, 2. Few solutions may be applied, 3. Resolvable at a medium level, 4. Resolvable completely

following 4 point system; however, 2 points is given for the decentralised distribution of responsibilities and the sophisticated training of personnel.

CONCLUSION

The light weight steel residence's frame is assembled from cold formed steel profiles. In the gaps between the profiles of the frame heat insulation material is placed and the frame is supplied with surface layers made of various materials, forming a layered structure. The light weight steel frame structure are constructed of C and U profiles with a dry, assembly style building technology. Numerous steel fasteners, stiffeners and other complementary profiles are connected to the basic elements of the structure. The applied materials filling the gaps between the elements of the frame not only perform heat insulation, but also meet acoustical requirements and they are an efficient fire protection tool. With the application of efficient heat insulation materials a good level of fire protection and an excellent heat and sound insulation can be achieved. The inside of wall surface cover is mostly made by plasterboard. Composite layers by wood as basic material (e.g. OSB) are preferably used as outside wall board cover and floor slabs. With this, we can exploit the advantage of high strength, which provides stiffening function. Steel construction components can be pre-measured and precut to exact specifications. On-site adjustments are generally not required.

Horizontal and vertical dimensions of space or structure elements, as well as coordination dimensions are selected among multiples of a specific dimensional module during design of the structure.

The objective of the lightweight steel residences production is to simultaneously decrease costs and scraps as well as to increase reliability, quality and production. A number of elements are required to achieve this; clean working environment should be created, standardization should be enabled, work plan should be arranged to complete work in a timely manner, work should be broken down into smaller parts to obtain higher quality products, minimum storage should be enabled, all work should be exposed to quality control, methods minimizing faults to "zero" should be selected, work teams should be improved, a regular work flow program should be applied and workers should be trained. In the scope of this study, the phases affecting material efficiency that cause structural physics and related problems during the production stage are identified.

The principal problems encountered during construction of industrialized lightweight steel residences are identified and accordingly, recommendations are presented. They are as follows.

- Unfavourable design of the production system.
- Bad control across all phases.
- The diffusion of solutions is complicated and hindered due to organizational problems.
- Physical problems with the buildings.

However, these problems can be mitigated and the comfort of the structure's users can be increased by implementing the above suggestions. In addition, economic benefits may be obtained by properly using materials, minimizing waste and completing the structure within the shortest time period possible.

As this study indicates, the first step in gaining these benefits is to clearly identify the problems related to residences constructed using lightweight steel systems. Only then can solutions be suggested for these problems. A sophisticated understanding of the problems will also allow the selection and implementation of an appropriate solution. In conclusion, the inherent efficiency of lightweight steel frame structures may be further enhanced by the elimination of problems at points to be encountered from production phase of construction elements to the delivery, assembly and usage phases by taking into consideration the solutions suggested here.

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