A FEASIBILITY STUDY ON THE NUMERICAL PRE-ASSEMBLY SIMULATION USING 3D LASER SCANNING MEASUREMENT

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ABSTRACT : The pre-assembly takes a large portion of the fabrication cost of steel bridges. In order to save the fabrication cost through the improvement of the conventional pre-assembling process, this research investigates a numerical pre-assembly simulation as an alternative to current pre-assembling process. The 3D laser scanning was utilized in site and measuring data for steel box were analyzed. The productivity of pre-assembly simulation system is compared with the conventional pre-assembling system. This paper identifies feasibility on the alternative pre-assembling process and then proposes the scheme of the pre-assembly simulation system development satisfying the current pre-assembly inspection of standards.

Key words : Numerical Pre-assembly Simulation, 3D Laser Scanning, Pre-assembling Process, Productivity

1. INTRODUCTION

In construction cost of steel bridges the percentage of the manufacturing cost amounts to approximately 70 percent [1], which indicates the feasibility of construction cost reduction by improving productivity in the fabrication process. It is the pre-assembling process that requires considerable manpower and cost in the fabrication process of steel bridges. The current pre-assembly has technical difficulties in supporting steel box to be zero-stress state and inefficiency in the requirement for pre-assembly site of a large scale, making an error of measurement by a tape measure, and the repetition of pre-assembling process on a fabrication site and a field of construction work [1].

In this regard, an alternative to current pre-assembling process will bring about positive effects such as shortened fabrication period and reduced pre-assembling costs.

In order to save the fabrication cost and reduce the duration through an improvement of the conventional pre-assembling process, this research investigates a numerical pre-assembly simulation as an alternative to current pre-assembling process.

The numerical pre-assembly simulation is performed on a computer and made up of measurement of steel box dimensions, 3D model formation using measuring data, and inspection of precision. The precision of a three-dimensional geometric data for the steel box has a great influence on the reliability of pre-assembly. In this research, the 3D laser scanning measurement system is applied to collect geometric data of steel box. It is the latest technology and is practically and efficiently used to gain 3D model data of the real thing. The 3D laser scanning was performed in the fabrication site and the differences between measuring data and design data for steel box were analyzed.

The productivity of pre-assembly simulation system is compared with the conventional pre-assembling process in the aspects of a commitment of man power, working days, and labor costs to investigate feasibility of the simulation system. The purpose of this paper is to identify feasibility on the alternative pre-assembling process and then propose the scheme of the pre-assembly simulation system satisfying the current pre-assembly inspection of standards.

2. MEASUREMENT METHODS

Most recently, Laser scanning and Photogrammetry are considered the appropriate method to produce realistic digital model. They are faster, more accurate, and cost-effective than traditional surveying method (total station). Whereas traditional surveying method (total station) is limited to collect geometric data of components and structures, laser scanning and photogrammetry system provide 3D digital model by image or point-based processing software.

Table 1 shows main characteristics such as the accuracy, collimation type, principle, range and measuring time for

Table 1. Comparison of measurement methods

Method	Main characteristic	Field of application
Traditional surveying methods (MONMOS, Total Station) [1]	• High accuracy : up to 0.1 mm • Using targets (touch type) : one point to one collimation • Principle : Triangulation method • Measurement range : 2m~1,000m (long range) • It needs much time to survey and high accuracy to set up a target on a surveying place	Most widely used to collect geometric data on structures and components
Photogrammetry (INCA3 camera) [1]	• Very high accuracy (0.005mm + 0.005 mm/m) • Using targets (touch type) : many points to one collimation • Principle : Triangulation method • Measurement range : close-range (10m using auto bar) • A lot of time is needed to set up targets, scale bars and auto bars	Industrial close-range photogrammetry : components and assembly inspection, reverse engineer -ing, surface shape analysis
3D Laser Scanner (GS100/200) [6]	• High accuracy (1 mm~6 mm) • No targets (non-touch type) : multishot (collecting 4,000~5,000 points/sec) • Principle : Triangulation method, Time-of-flight method • Measurement range : 1m~200m (middle range) • The shortest measuring time among other methods is required.	The most recent technology : plant , instrument, culture, construction/civil Eng.

traditional surveying methods (MONMOS, total station), photogrammetry (INCA3 camera) and 3D laser scanner (GS100/200). Both total station and phtogrammetry is touch type required targets (MONMOS : rotary target, reflection sheet target, bolt target etc, INCA3 camera : coded target, edge target, auto bar, scale bar etc), and the accuracy and resolution are affected by a target sticking type. On the other hand, the laser scanner is non-touch type required no target. The productivity of touch and non-touch type is evaluated by specially comparing total station (MONMOS) and laser scanner (GS100). The automated measurement system and exclusive place are required to collect the exact geometry data but due to the current circumstance of domestic industry the survey of steel box is made in the fabrication site.

The laser scanner GS100 (time-of-flight method long range scanner, real-time video transmission) is applied in this paper and measurement process are as follows (Figure 1):

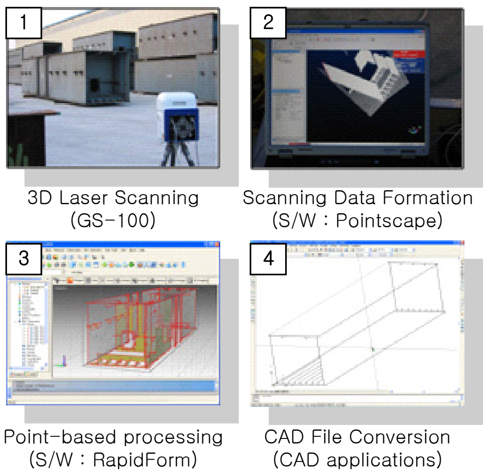

Figure 1. Numerical Pre-assembly System

(1) Planning measurement of steel box
(2) Laser scanner set up and preparation
(3) Preview of measuring part (4) scanning start
(5) transmission of scanning data (6) 3D digital model

Laser scanning method needs no target but the reference points (white ball, 2~several points) must be installed on the steel box to combine partially scanned parts. Before scanning start, measuring part is previewed by a built-in camera and scanning resolution is adjusted. The scanning data is transmitted to laptop and then the result is checked by the exclusive application (S/W : Pointscape). The scanning process involved collecting points of x, y, z coordinates in user-defined space generally known as point cloud.

Parameters such as speed, period, and cost were cumulated to assess to determine whether laser scanner were practical when compared to a tape measure and total station.

3. FEASIBILITY STUDY

3.1 Accuracy

Recent advances in laser scanning and 3D modeling data have the need to evaluate the accuracy of measuring data. As shown in Table 2 and Figure 2, the measuring result of laser scanner (GS100) is within the limits of allowable errors and indicates that the accuracy required to apply the numerical pre-assembly simulation satisfies the inspection specification.

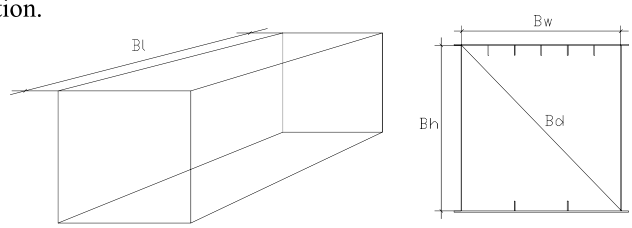

Figure 2. Dimensions of steel box

Table 2. Using 3D Laser Scanning

(unit : mm)

Item	Survey Data		Design Data	Allowable Error
	Tape Mea.	Laser Scan.		
Bw	2,400	2,402(2,404)	2,400	± 4 mm
Bh	2,499	2,503	2,500	± 5 mm
Bd	3,464(3,467)	3,470	3,466	
Bl	11,315	11,311	11,315	± 4 mm

3.2 Productivity

Laser scanning and total station surveying are compared with the current pre-assembly process in terms of cost, duration, and manpower to verify which method is effective.

Table 3. Productivity of current pre-assembling process

Tasks (/20 boxes)	Number of Labors	Duration (Days)	Cost (USD)
Assembling	4	3	$1,200
Disassembling	4	1	$400
Drilling etc.	7	2.5	$850
Inspection	1	0.5	$75
Total	16	7	$2,525

※ Note : ($ 1 (USD)= ₩1,000 (KRW))

Table 4. Productivity of total station [2]

Tasks (/1 box)		Number of Labors	Duration (Minutes)	Cost (USD)
Data collection	Setting	survey engineer 1	20	$150
	Survey		20	
	Moving		10	
	Setting	assistance 1	20	$50
	Survey		20	
Office processing		1	30	$150
Total		3	120	$350/day

Table 5. Productivity of 3D laser scanning

Tasks (/1 box)		Number of Labors	Duration (Minutes)	Cost (USD)
Data collection	Setting	survey engineer 1	10	$150
	Survey		20	
	Moving		5	
	Setting	assistance 1	5	$50
	Survey		20	
Office processing		1	30	$150
Total		3	90	$350/day

Cost, manpower, and duration data from each survey method are listed in Table 3, Table 4 and Table 5. The subject of this research is 1 span (20 boxes), and required time and cost per 1 box are estimated by total stations and laser scanners. Total cost of the current pre-assembly process is estimated at $2,525. Depending on manufacturers, bridge types and quantity, the cost may be differed.

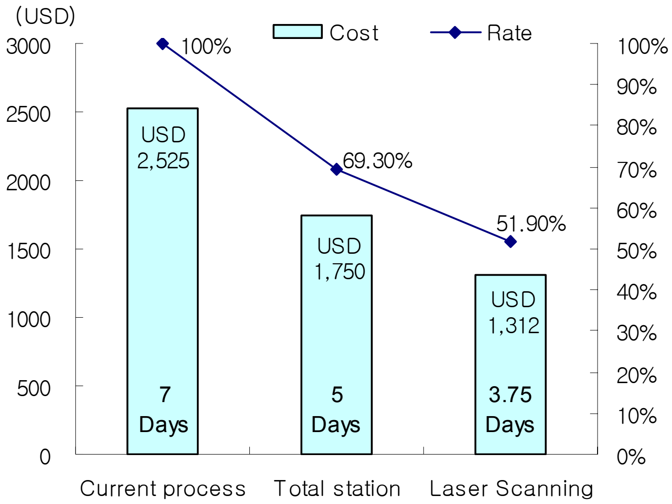

Figure 3. Comparison productivity (/20 boxes)

MONMOS and laser scanner is divided into 3D geometry data collecting and post-processing collection data and requires a three-person crew (survey engineer : 1 person, assistance : 1 person, and S/W operator : 1 person). MONMOS needs about 90 minutes and GS100 requires 60 minutes when measuring one box. Office processing will require 30 minutes each.

In the case of 20 boxes assembly, the total cost of MONMOS is about $ 1,750 (=5(days) x $350/day) and laser scanner is about $ 1,312 (=3.75(days) x $350/day) (Figure 3). MONMOS comes into about 69.3 % and GS100 about 51.9 % compared to the current pre-assembly cost. This result is restricted to 20 boxes assembly. Therefore the reduction effect is expected to increase in the case of overall steel bridge project.

4. SCHEME OF THE PRE-ASSEMBLY SIMULAT -ION SYSTEM DEVELOPMENT

4.1 Pre-assembling Process and inspection standards

The pre-assembling process indicates a successive course required to inspect manufacturing errors, inferiorities and so forth through assembling a steel bridge at the manufacturing site prior to erecting that on the construction site. It is composed of measuring its dimensions and inspecting its configuration, connection conditions and bolt holes after pre-assembly (Table 6) [5].

It is stipulated in the domestic specifications that pre-assembly be carried out partially or be omitted in case either there are many of same type structures fabricated or the elements are manufactured to be compatible. As for foreign practices, other methods which may be regarded as alternatives to the pre-assembly are acknowledged to be equivalent, and those are practically applied [1]. Therefore, the domestic regulations relevant to the pre-assembly are deemed to be complemented and revised in order for practical application, research, and development of alternative methods to the pre-assembly.

Table 6. Inspection standards of Pre-assembling process

Accuracy	Item
Accuracy of member	- Height, Width and Length of member - Bending of compression member
Accuracy of pre-assembling	- Total Length, span - Interval between center of beam and truss - Filed splice - Camber, Expansion joint, Flatness
Accuracy of bolt hole	- Nominal diameter - Bolt hole stagger

4.2 Configuration of simulation system

The configuration of the pre-assembling simulation is categorized into three sections [4] as shown in Table 7. Even though the design data for steel bridges are drawn up in two -dimensional information, techniques which can convert these into three dimensions are required to compare with the measuring model. In addition, measuring techniques to obtain three dimensional geometrical data from a fabricated steel bridge product are indispensable. The kernel know-how of the simulation system is the materialization of the pre-assembling process which allows to make it possible drawing a dimension comparison between the measuring model and the actual structure and inspecting the connection configurations and conditions of elements [1].

Table 7. System configuration

System	Property
Design Data Conversion system	- 2D design data → 3D design model - link to measuring model
Measuring System	- Collect 3D geometry data of fabricated steel box - Produce 3D digital model from survey data
Simulation System	- Inspect the accuracy of member → Inspection report - Inspect the accuracy of pre-assembling → Inspection report

The configuration diagram of the numerical pre-assembly system is shown in the figure 4 below. The inspection of member accuracy is carried out by sharing information of members, which can be secured through the linkage (member codes) between the measuring model constituted by measuring results and the design model created from design data. After the inspection of member accuracy being completed, the pre-assembly inspection shall be carried out, which checks whether or not the inspection items such as the joint space, camber, expansion joints, the distance between box centers, span lengths and the total length are satisfied in accordance with each criteria. After that, the inspection report regarding pre-assembly shall be prepared in the end phase.

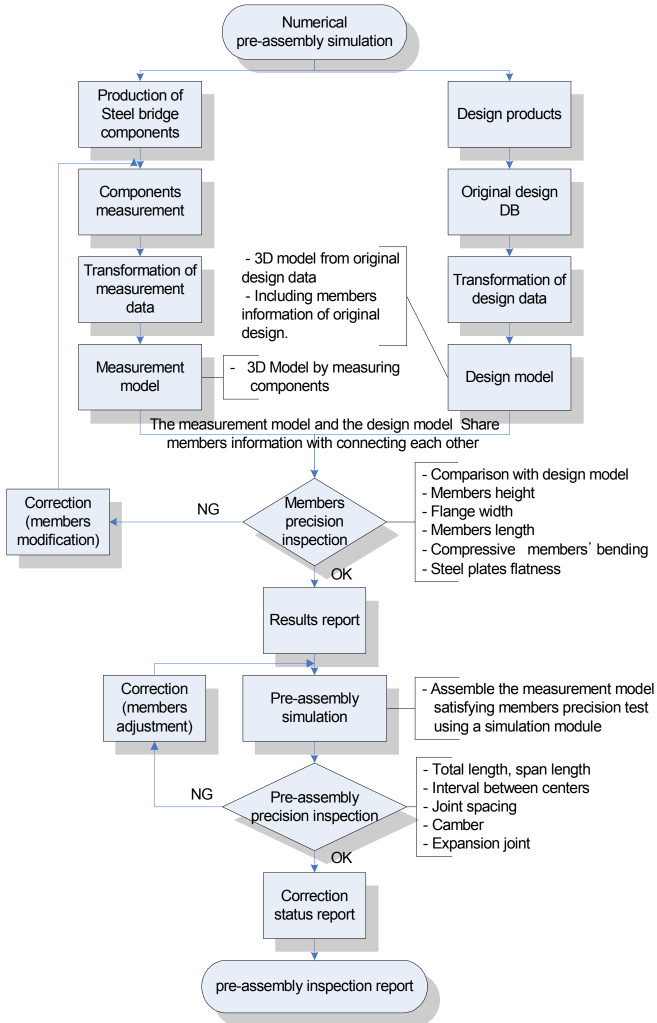

Figure 4. Numerical Pre-assembly System

It is the essential element of the system development to embody the algorithm of simulation system since the simulation system may be executed based on the reciprocal compatibility and interaction of CAD application, 3D measuring system and simulation software.

4.3 Inspection of member accuracy

The inspection of member accuracy is the process to check whether or not manufacturing errors are within the allowable limits by comparing design data with the actual dimensions of a manufactured steel box. The member accuracy shall be verified in accordance with the inspection items specified, and the utilized information regarding each member is supposed to be obtained from the three dimensional design model.

Information on members can be shared through linking the name codes of the measuring model and the design model, which provides information regarding member dimensions such as the box height and length and the flange width. In case the manufacturing error does not exceed the allowable limit, the inspection of member accuracy shall be completed, and the inspection report is prepared. Otherwise, the report regarding member amendments shall be provided, and drawings are revised (Figure 5).

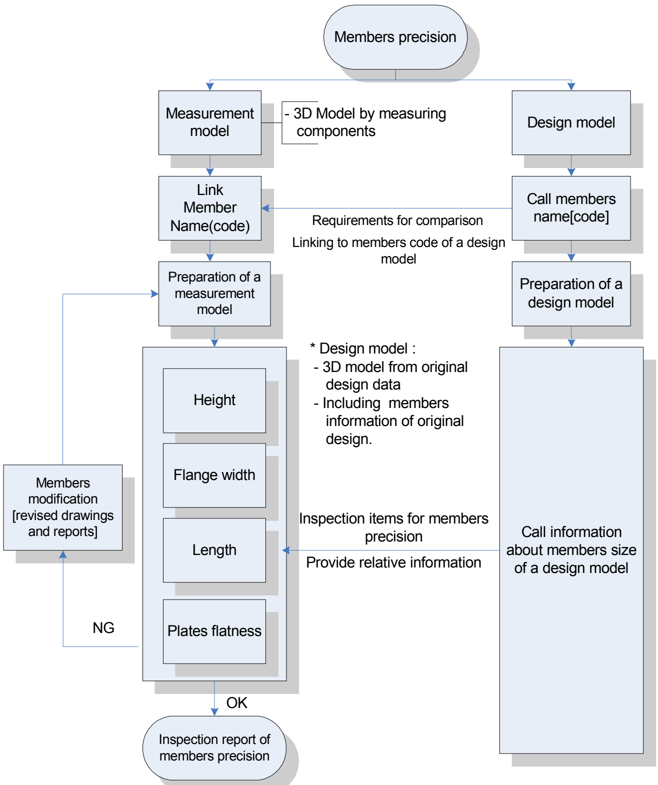

Figure 5. Inspection of member accuracy

4.4 Inspection of pre-assembling accuracy

The inspection of pre-assembling accuracy is the process to check over the overall configuration and conditions of a steel box assembling. The algorithm to materialize an actual pre-assembling process is described in the figure 6. First of all, the baseline is constituted from design data to place the measuring model. Along the baseline, the first placement is completed and the initial values for the second placement are obtained. At the second arrangement phase, the relocation or adjustment of a steel box is required to satisfy the allowable limits after estimating the distance between the datum points of each member. The accuracy inspection shall be performed in the order of joint space, camber, expansion joint, distance between box center, span and total length. In case a specific part is detected to exceed the allowable error, the members are adjusted and relocated, the inspection shall be accomplished all over again from the very beginning in order to comprehend the influence to other inspection items due to member adjustment.

The member arrangement algorithm that the five inspection items are classified into the x, y, z axes is constructed to minimize interactions among the inspection items and to ensure the improvement of system execution speed and expediency as described in the figure 7. As shown in the above, a joint space, an expansion joint, and a span and the total length-x, a camber-z and the distance-y between the box centers are set up into the x, z, y axis, respectively. The user selects the datum point to estimate the distance between the support point on the abutment and the pier (fixed points), the starting point of the member arrangement, and the steel box. The joint space, camber,

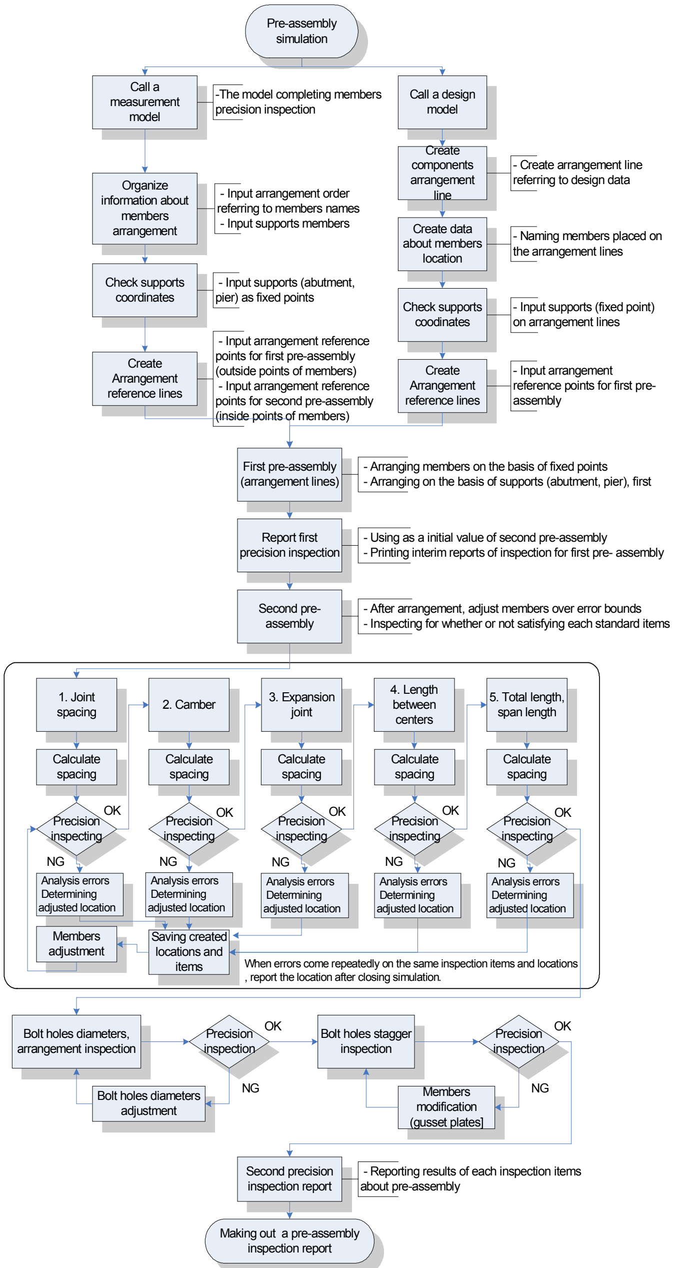

Figure 6. Inspection of Pre-assembly accuracy

expansion joints, span lengths and the total length centering around the datum point shall be calculated and checked whether or not the allowable limits are exceeded. The distance between the datum points are computed based on the cartesian coordinates and only referred to values on the same axis. If identical errors occur at the same inspection item, the simulation system is set up to be terminated and to generate error message to users. However, on condition that the inspection criteria are satisfied through the relocation and adjustment of members, the inspection report for pre-assembly shall be printed out, and pre-assembly simulation is completed.

5. CONCLUSION

It is verified that the laser scanning method has the accuracy to satisfy the inspection specification of pre-

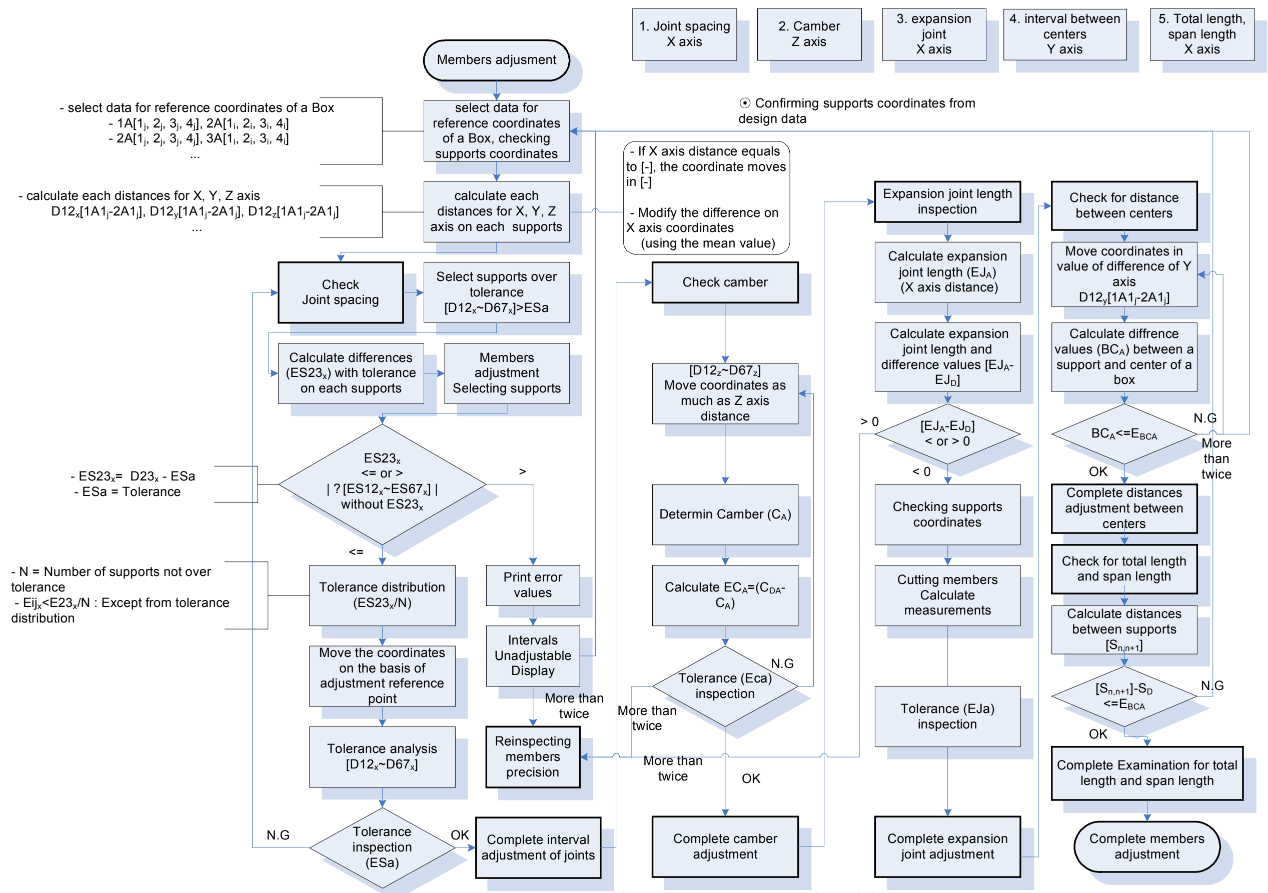

Figure 7. Member arrangement algorithm

assembly. Laser scanner and MONMOS are compared with the current pre-assembly process in terms of duration, cost, and manpower. MONMOS could result in a total reduction of 2 days and laser scanner (GS100) could result in a total reduction of 3.25 days compared with the duration of the current process. And MONMOS comes into about 69.3 % reduction effect and laser scanner comes into about 51.9 % compared to the current pre-assembly cost. The use of laser scanning could result in increasing productivity and reducing the overall cost of the steel bridge fabrication.

This paper proposes the scheme of the pre-assembly simulation system development satisfying the current pre-assembly inspection of standards. The configuration of the pre-assembling simulation is categorized into three sections. The kernel know-how of the simulation system is the materialization of the pre-assembling process and it is the essential element of the system development to embody the algorithm of simulation system based on the reciprocal compatibility and interaction of CAD application, 3D measuring system and simulation software. There is a general lack of awareness of the data processing technology and efficiency it can offer and it is necessary to improve the integration of laser scanning and 3D data processing technology.

The domestic regulations relevant to the pre-assembly are deemed to be complemented and revised in order for practical application, research, and development of alternative methods to the pre-assembly.

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