

Geometric control of short-line match casting using Computational BIM

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Abstract

Short-line match casting is a method of producing segmental pre-cast concrete bridges. This segment production process is centralized, repetitive, compact, and is easily adaptable to geometry variations such as plan, vertical, and transition curves. But the main challenge is the complexity of geometry control and the need for high accuracy. The complexity arises due to the changing coordinate system and the accumulation of errors for each segment. Although the method can adapt geometries involving transition curves, it is susceptible to geometric errors that accumulate over the entire span resulting in significant deviation from the alignment. This calls for rigorous geometry control during the casting process. The current work proposes a framework/workflow, called the Geometric Error Minimization for Bridge Segment Casting (GEMBSC), for minimizing geometric errors in segmental casting alignment in real-time. It involves the formulation of an iterative geometric control algorithm using the least-square method and a software tool to manage the geometric control workflow. Dynamo, a computational BIM tool, was used to extract the coordinates from the BIM model and perform coordinate transformations that feed to the surveying instruments. Subsequently, the tool compares the as cast data with the planned geometry data and runs the error minimization algorithm to output the corrected coordinates for the casting of subsequent segments. The algorithm was validated based on past real-world data by the results obtained for the same data through a proprietary software application. The results indicated that GEMBSC is effective in minimizing errors along with providing other benefits such as savings in time and effort involved in error corrections with existing software use.

Keywords –

Computational BIM, Short-line match casting, Dynamo Visual Programming

1 Introduction

Segmental pre-casting of prestressed concrete bridges is a technique that offers many benefits to bridge construction in terms of time savings and quality of construction. The casting of all the segments of the bridge takes place in the casting yard thereby ensuring quality control of the segments [1]. One of the key components of the segments is the shear keys that need to interlock accurately during the erection process. Improper joints between segments coupled with high post-tensioning forces could lead to cracking and subsequent collapse of the final structure. Hence, accuracy in geometries of the segments during the casting is crucial to the process.

The casting of segments in the yard typically takes place either using the long line method or the short line method. In the Long line method, the moulds of the whole span are aligned as per the required geometry and the segments are cast one by one in their respective positions. However, long-line casting elevation has limitations when casting spans with large horizontal and vertical curvature due to space requirements [2].

On the other hand, in the short line method, one segment is cast at a time. As shown in Figure 1, the segment which is cast earlier acts as a formwork on one side whereas a fixed formwork is present at the other end.

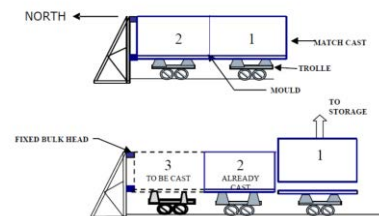


Figure 1: Schematic of Short-line match casting

After the segment is cast the previously cast segment is moved to the stacking yard and the current segment is moved to the position of the previous segment. This process is repeated till all the segments are cast. Hence, the short line approach is preferred over the long line

method in projects with space restrictions and spans with higher curvatures [3].

Although the method can adapt geometries involving intricate transition curves [4], it is susceptible to geometric errors that accumulate over the entire span resulting in significant deviations from the plan [5]–[8]

- Misalignment while translation from wet cast to match cast position
- Sliding of the segment in the match cast position from its fixed position due to the expansion of iron rails on which the whole assembly moves
- Movement of form mounted on rails during concreting due to vibrations
- Movement/ settling of jacks on which the segment is supported.
- Movement of dry segments due to horizontal pressure from wet concrete.
- Mistakes/errors in surveying
- Other human errors like positioning of punch plates.

This calls for rigorous geometric control during the casting process. Several proprietary geometry control software is available to streamline and simplify the surveying operations. These geometry control procedures are based on surveying of elevations combined with the double measurement with a tensioned tape of the sides and diagonals of rectangular top slabs [6]. In addition to the cost incurred in the procurement of such software and its utilization in correcting geometric errors, the casting personnel must often spend enormous amounts of time and effort in calculating these errors and minimizing them in the casting process. Therefore, there is a need for a framework/workflow for automatically minimizing geometric errors in segmental casting alignment in real time [9].

The geometric control process, if implemented with BIM, would lead to real-time updating of the BIM model which could further provide several other advantages. Hence, the current work aims to develop a model/framework for automated elimination of geometric errors and updating of the BIM model.

Towards this end the objective of the current work was to formulate a workflow for the real-time geometrical error minimization during segment casting called the Geometric Error Minimization for Bridge Segment Casting (GEMBSC). The formulation of the workflow mainly involved the formulation of a mathematical solution and its translation to visual programming script. The framework consists of four modules: Coordinates exporter from Revit model, Starter Segment Setup, Typical Segment Setup, and Generation of As Cast Model. The model was tested using past real-world data of segment casting. The results were compared with the results obtained from proprietary software.

This paper is organized into six sections. The second section discusses the existing studies in geometric error minimization in bridge segment casting. The third and fourth sections discuss the formulation of the mathematical solution and the description of the various modules of the GEMBSC. The final two sections comprise of the Results and the Summary and Conclusion.

2 Related Work

The geometric control must start from the conceptual design phase and be kept in mind throughout the design, detailing the casting curve, preparing production plan, and shop drawings phases [10]. Researchers have discussed techniques for geometric control in segmental match casting. Among the earliest works, [11] provided guidelines and steps to minimize geometrical errors caused solely due to twists. Although the suggestions are useful in preventing geometrical errors, they do not provide real-time predictions of errors during the casting process. A researcher [6] proposed a procedure that could be utilized in geometrical control software. However, the study does not consider a few types of errors and therefore has limitations. Also, the correction of the errors in the proposed software occurs in a single step which could lead to sharp changes in the bridge alignment. Similarly, [8] proposed a new MATLAB based platform for geometric corrections of bridge segments and implemented it using a case study. Similar studies have been conducted by researchers such as [4], [12], [13]. Most of the above-mentioned techniques do not focus on BIM integration for monitoring and correction of geometric errors. Further, several of the existing studies have been conducted using proprietary software.

A researcher [14] has proposed a BIM and 3D laser scanning framework to produce an automated and reliable dimensional and surface quality assessment for precast concrete elements which is more specific to the surface defect identification. A similar method can be applied to automate the process of collecting the data of the precast segments. However, for the purpose of geometric control of a bridge segment, which is governed by six control coordinates, processing of point cloud of entire segment may be computationally expensive at this point in time.

From the review of literature on the existing techniques in geometric corrections, it is evident that different techniques focusing on geometrical error minimization for bridge segment casting have been explored. However, most of the techniques have limitations in terms of effectiveness and implementation and could also have cost and time implications. Further, currently available BIM related tools and interfaces could

facilitate simpler geometrical formulations for the automation of the workflow on geometric correction and revision of BIM as cast models.

3 Geometric error compensation:

There are two strategies to compensate for the geometric errors in the casting of any segment, single step and progressive nullifying of errors. To avoid the sharp changes and kinks in bridge alignment that could result from single step nullifying of errors, progressive minimization of errors was adopted. This strategy involves gradual correction of errors by converging the fore joint coordinates of the succeeding few segments toward the planned alignment.

The Least Square Method is a popular method used by researchers for correction of geometric errors. The least squares method is applicable for adjustment of the basic measurements made in surveying, including observed differences in elevation, horizontal distances, and horizontal and vertical angles. The principle of least square is that if the sum of the squares of the errors in a system are minimized, the points will fit best in the system.

3.1 Mathematical Solution Formulation

The logic used in error correction using Least Square method is demonstrated in Figure 2.

In Figure 2, S1 is the span of first segment
S(last) is the last segment of the span

S(n-1) is the previous segment in which error has occurred

S(n) is the current segment for which the corrected coordinates need to be calculated

Fc = Coordinates of the first segment at the center

Lc = Coordinates of the last segment at the center

Pe, Pc, and Pw = Planned Coordinates of the previous segment at East, Center and West side

Pae, Pac, and Paw = Actual coordinates of the previous segment at East, Center and West side

Ce, Cc, and Cw = Planned coordinates of the current segment at East, Center and West side

As shown in Figure 2, the distance between Pe and Ce represents the width of the segment and the distance between Ce and Cw represents the length of the segments. The aim of the geometry correction exercise here is to find the revised coordinates of the points Ce, Cc and Cw. Figure 2 also illustrates the network of relationships between segment coordinates and errors.

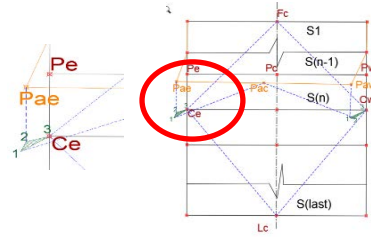


Figure 2: Network of relationship between segment coordinates and errors

A relationship between actual coordinates of the previous segment (Pae) and the succeeding segments (Ce) is set up such a way that it represents the same relationship that existed between the planned coordinates (i.e., between Pe and Ce). This relationship indicates a new position for point Ce. Since the system is over-determined, a unique point for Ce is not obtained but three different points 1,2,3 as shown in the figure are obtained. Applying least square principle we will find a point within the boundaries of the three different points suggested (a hatched region in the figure) that has the least sum of squares from all the boundary points (1,2 and 3).

Hence, the corrected coordinates of point Ce and Cw are obtained by considering them as floating points. The solution which is the best fit is obtained after the rigorous iterative procedure of minimizing the errors. The point Cc will then be computed as a midpoint between Ce and Cw. The error which occurred in segment S(n-1) is not nullified yet, but the error has reduced, and the alignment is tending towards the planned alignment. When the same calculation procedure is repeated for the succeeding segments S(n+1) and S(n+2) and so on, the error gradually reduces, and the actual alignment converges with the planned alignment.

Since the horizontal alignment of the bridge is governed by the center coordinates and the elevation is governed by the outer four coordinates the X, Y coordinates and Z coordinates are calculated separately. Hence two networks of relationships are set up, one for horizontal adjustment and another for leveling adjustment. In the horizontal network, the X and Y coordinates of Ce and Cw must be determined. Therefore, there are four unknowns present in the horizontal network. In the vertical network, there are two variables, the Z coordinates of the points Ce and Cw.

Setting up relationship between points: The relationship between the points can be modeled in different ways such as position, distance, and direction using method of triangulation or using only position and distance in method of trilateration. Trilateration network is much easier and is adequate for this case as the measurement of errors are in terms of distances.

Any Linear distance between i and j can be written as:

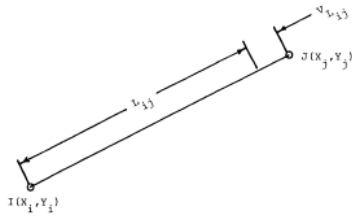


Figure 3: Error in measurement between points two points

$$L_{ij} + V_{ij} = F(X_i, Y_i, X_j, Y_j) \text{ (figure 3)}$$

$$F(X_i, Y_i, X_j, Y_j) = \sqrt{(X_i - X_j)^2 + (Y_i - Y_j)^2}$$

Here, L_{ij} is the observed length of the line IJ , V_{ij} is the error in the observation. X_i, Y_i, X_j and Y_j are the X and Y coordinates of the point I and J respectively.

Applying Taylor's series approximations and neglecting the higher order terms, the following equations were derived.

$$\begin{aligned} X_i &= X_{i0} + dX_i & Y_i &= Y_{i0} + dY_i \\ X_j &= X_{j0} + dX_j & Y_j &= Y_{j0} + dY_j \end{aligned}$$

By evaluating the partial derivatives of the function F , and solving we get

$$K_{L_{ij}} + V_{ij} = \left[\frac{X_{i0} - X_{j0}}{IJ_0} \right] (dX_i) + \left[\frac{Y_{i0} - Y_{j0}}{IJ_0} \right] (dY_i) + \left[\frac{X_{i0} - X_{j0}}{IJ_0} \right] (dX_j) + \left[\frac{Y_{i0} - Y_{j0}}{IJ_0} \right] (dY_j)$$

$$\text{Where } K_{L_{ij}} = L_{ij} - IJ_0$$

$$IJ_0 = \sqrt{(X_{j0} - X_{i0})^2 + (Y_{j0} - Y_{i0})^2}$$

Based on the above result, the trilateration relationship between points $F_c - C_e$ and F_c to C_w is setup considering C_e and C_w as floating points with planned coordinates as initial approximations. Since the error are present, the actual distance between F_c and C_e will be $L1'$ instead of $L1$. The relationships can be represented in the form of a matrix. Since there are relationships containing error values (from point P_{ac}), the least square method mainly involves finding a fit for the points C_e and C_w which will minimize the error of the whole system of relationships. Since this method finds the difference that needs to be added to the initial approximations of the points C_e and C_w , it is called the method of variation of coordinates.

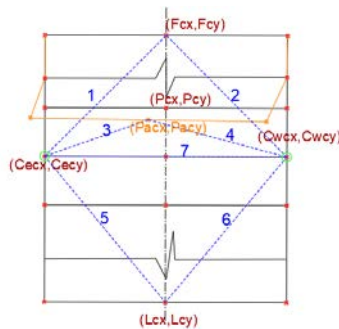


Figure 4: Horizontal network relationships

The matrix of relationships can be represented as:

$$AX = K + V$$

Where,

$$A = \begin{pmatrix} \frac{C_{ecx} - F_{cx}}{L1} & \frac{C_{ecy} - F_{cy}}{L1} & 0 & 0 \\ 0 & 0 & \frac{C_{wcx} - F_{cx}}{L2} & \frac{C_{wcy} - F_{cy}}{L2} \\ \frac{C_{ecx} - P_{acx}}{L3} & \frac{C_{ecy} - P_{acy}}{L3} & 0 & 0 \\ 0 & 0 & \frac{C_{wcx} - P_{acx}}{L4} & \frac{C_{wcy} - P_{acy}}{L4} \\ \frac{C_{ecx} - L_{cx}}{L5} & \frac{C_{ecy} - L_{cy}}{L5} & 0 & 0 \\ 0 & 0 & \frac{C_{wcx} - L_{cx}}{L5} & \frac{C_{wcy} - L_{cy}}{L5} \\ \frac{C_{ecx} - C_{wex}}{L7} & \frac{C_{ecy} - C_{wcy}}{L7} & \frac{C_{wcx} - C_{ex}}{L7} & \frac{C_{wcy} - C_{ey}}{L7} \end{pmatrix}$$

$$X = \begin{pmatrix} dX_e \\ dY_e \\ dX_w \\ dY_w \end{pmatrix} \quad K = \begin{pmatrix} L1 - L1' \\ L2 - L2' \\ L3 - L3' \\ L4 - L4' \\ L5 - L5' \\ L6 - L6' \\ L7 - L7' \end{pmatrix}$$

Where,

$$L1 = \sqrt{(C_{ex} - F_{cx})^2 + (C_{ey} - F_{cy})^2}$$

$$L1' = \sqrt{(C_{ecx} - F_{cx})^2 + (C_{ecy} - F_{cy})^2}$$

$$L2 = \sqrt{(C_{wx} - F_{cx})^2 + (C_{wy} - F_{cy})^2}$$

$$L2' = \sqrt{(C_{wex} - F_{cx})^2 + (C_{wcy} - F_{cy})^2}$$

Similarly, $L3$ to $L7$ and $L3'$ to $L7'$ can be computed between other points shown in the image 4

A is the matrix of relationships

X is the matrix of variation of coordinates $X_e, Y_e, X_w,$ and Y_w

K is the matrix of the difference between planned and actual distances.

V is the matrix containing the errors.

Upon solving for the matrix X , we get the correction factor which needs to be applied to the planned coordinates of subsequent segments to be cast.

The same logic was utilized for the vertical error adjustment. The above mathematical operations were modelled using visual programming tools.

3.2 The GEMBSC framework

The Figure 5 shows the flow chart of the complete operation of the Geometric correction algorithm. As shown in Figure 5 the solution framework consists of four main components: 1. Coordinate Exporter, 2. Starter segment Set-up, 3. Typical Segment correction, and 4. As cast model generator.

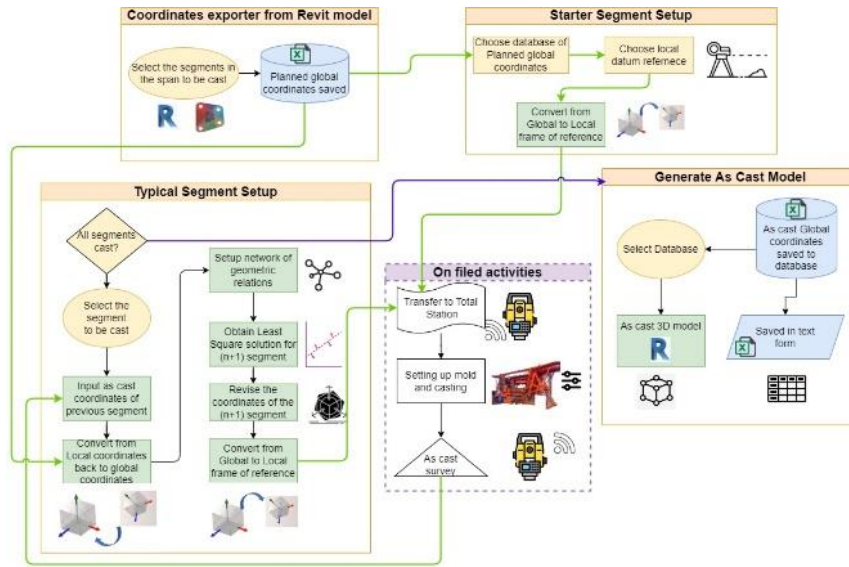


Figure 5: Solution framework

3.2.1 Module-1: Coordinate Exporter

The steps corresponding to Module-1 shown in Figure 5 are discussed below.

1. The model elements selected are filtered based on the Family type of “Control Points”.
2. The Control points which are marked in order of East, centre and west for each joint by the designers. These are extracted and sorted based on the index number of the point in the list.
3. Each joint has three control coordinates, hence the points at index 0,3,6,9 and so on are stored in a list of East control points, Points at index 1,4,7,10, etc. are stored in Center control points list and the remaining points are stored in the West control point list.
4. These lists are combined in a standard format in a multilevel list
5. The data is written to an Excel file, from the path which will be chosen by the user.

Figure 6 shows the interface of coordinator exporter module whereas Figure 7 shows the screenshot of the output of the coordinate exporter module.

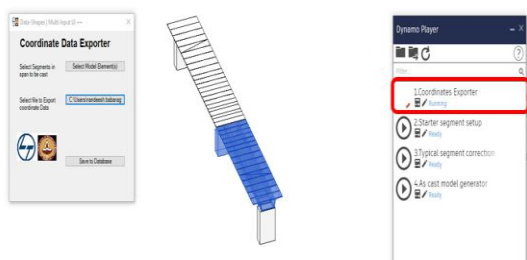


Figure 6: Coordinate Exporter module

Joint	XE	YE	ZE	XC	YC	ZC	XW	YW	ZW
0	-248.5	-8.52673	10.66026	-246.6	-8.52673	10.66026	-244.1	-8.52673	10.66026
1	-244.1	-0.85228	10.66026	-241.2	-8.52673	10.66026	-241.2	-0.85132	10.66026
2	-241.2	8.82266	10.66012	-238.3	-8.52673	10.66026	-238.3	-0.85358	10.66026
3	-238.3	8.82262	10.66026	-235.4	-8.52673	10.66026	-235.4	-0.85197	10.66026
4	-235.4	8.82246	10.66026	-232.5	-8.52673	10.66026	-232.5	-0.85296	10.66026
5	-232.5	8.82183	10.66026	-229.6	-8.52673	10.66026	-229.6	-0.85208	10.66026
6	-229.6	8.82205	10.6602	-226.7	-8.52672	10.66026	-226.7	-0.85182	10.66026
7	-226.7	8.82099	10.66026	-223.8	-8.52665	10.66024	-223.8	-0.85182	10.66026
8	-223.8	8.82217	10.66026	-219.8	-8.52673	10.66026	-219.8	-0.85182	10.66026
9	-219.8	8.82241	10.66026	-215.8	-8.52673	10.66026	-215.801	-0.85182	10.66026
10	-215.8	8.822194	10.66021	-211.8	-8.52673	10.66026	-211.8	-0.85182	10.66026
11	-211.8	8.822196	10.66021	-207.8	-8.52636	10.66026	-207.8	-0.85182	10.66026
12	-207.8	8.822626	10.66026	-203.8	-8.52673	10.66026	-203.799	-0.85182	10.66026
13	-203.8	8.822305	10.66026	-199.8	-8.52653	10.66026	-199.801	-0.85182	10.66026
14	-199.8	8.822143	10.66023	-195.8	-8.5267	10.66026	-195.801	-0.85182	10.66026
15	-195.8	8.822524	10.66026	-191.8	-8.52624	10.66026	-191.799	-0.85182	10.66026

Figure 7: Output of the coordinate Exporter module

3.2.2 Module-2: Starter Segment Setup

The steps corresponding to Module-2 shown in Figure 5 are discussed below.

1. From the extracted global coordinates, the control coordinates of the starter segment are filtered out.
2. The joint which should match cast with the second segment should be on the bulkhead side (Figure 8). Therefore, the center coordinate of this edge is made the origin of the newly created local coordinate system.
3. The X, Y and Z axes are defined for the newly created coordinate system. The X axis is the vector between the created origin (center coordinate) and the East control point of the same edge. The Z axis is defined by creating a point with the same X and Y coordinate of the Origin with an arbitrary high Z coordinate value (say 1000) and defining a vector between this point and origin.

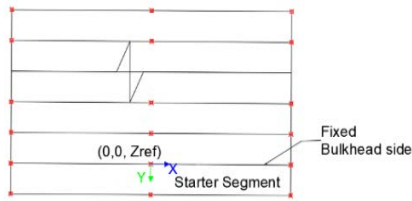


Figure 8: Starter segment Local coordinates

4. The Y axis is defined as the cross product between these vectors of the Z-axis and X-axis, to satisfy the left-hand rule of the coordinate system.
5. The other points which are filtered out from the list in step-1 are read relative to this coordinate system, to obtain the X and Y local coordinates of all the points in the starter segment.
6. The Z coordinates depend on the user input Z-reference, Therefore the Z coordinates of the points are calculated relative to this value.

Figure 9 shows the interface of the starter segment setup module whereas Figure 10 shows the screenshot of the output starter segment setup module.

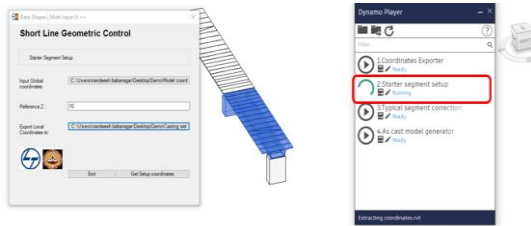


Figure 9: Starter segment setup module

Station	NORTHING	EASTING	ELEVATION
SE	2.58042	6.82873	10.00000
SC	1.90880	5.05138	10.00000
SW	1.02510	2.71278	10.00000
NE	8.20410	0.00000	10.00000
NC	0.00000	0.00000	10.00000
NW	7.17990	-2.71312	10.00000

Figure10: Output of Starter segment setup module

3.2.3 Module-3: Typical Segment Correction:

The steps corresponding to Module-3 shown in Figure 5 are discussed below.

1. From the extracted as-planned global coordinates, the control coordinates of the currently selected segment and the previous segments are filtered out.
2. The as-cast local coordinates of the previous segment are obtained from the total station input, now this must be converted to global coordinates to know the errors in casting. But the local origin of these coordinates lies at the fixed bulkhead center. Since the bulkhead is rigid and fixed, any deviations that have happened would be on the other edge of the segment.
3. To convert the local to global coordinates, the

edge/joint, which is on the match cast side, whose coordinates are known should be taken as reference (Fig.11). The East coordinate of the match cast joint is taken as reference and its coordinates are equated to the as-cast global coordinates of the same edge which was formed during casting of the previous segment. With this point as a reference, the transformation of other points is made with the help of translation and rotation matrix to convert the as-cast local coordinates to global coordinates. Fig11 illustrates this logic.

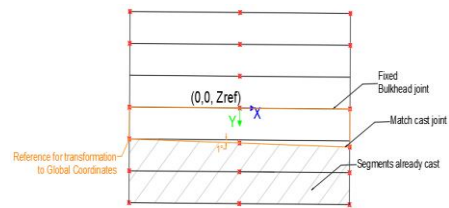


Figure 11: Logic of conversion transformation from local to Global coordinates

4. Based on the as-cast global coordinates and planned global coordinates, the matrix of relationships is set-up and solved using least squares criteria. The corrections to be applied to the planned coordinates of the current segment is obtained. Similarly, the elevation network is also set-up and solved to get the corrected Z-coordinates.
5. From the corrected coordinates obtained, the new local coordinate system is defined at the joint which will be on the bulkhead side. This method is similar to the method followed to convert the global coordinates to local coordinates in starter segment setup.
6. The output of the corrected local coordinates is obtained in excel file which can then be transferred to total station for staking out the operation.
7. Also, the as-cast global coordinates obtained by transformations as explained in earlier steps is then stored in the database. This data can later be used to generate the as-cast model of the bridge.

Figure 12 shows the interface of typical segment correction module whereas Figure 13 shows the screenshot of the output of the coordinate exporter module.

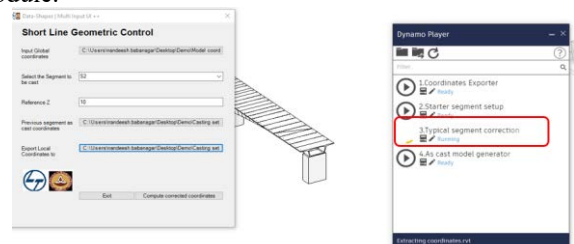


Figure 12: Typical segment correction module

B	C	D	E
-244.1	-8.52673	10.66026	Left
-246	-8.52673	10.66026	centre
-248.5	-8.52673	10.66026	Right
-248.5	-0.85228	10.66026	Left
-251.4	-8.52673	10.66026	centre
-251.4	-0.85132	10.66026	Right

A	B	C	D
Station	Northing	Easting	Elevation
NE'	-7.675	2.900	100.000
NC'	0.000	2.900	100.000
NW'	7.674	2.900	100.000
NE	7.674	0.000	100.000
NC	0.000	0.000	100.000
NW	-7.674	0.000	100.000
SE'	-7.675	5.800	100.000
SC'	-0.004	5.800	100.000
SW'	7.674	5.800	100.000

Figure 13: As cast global coordinates and local coordinates output from Typical Segment correction

3.2.4 Module-4_As cast model generator:

The steps corresponding to Module-4 shown in Figure 5 are discussed below.

1. The adoptive family type of the cross section is imported to Dynamo
2. From the as-cast global coordinates data, the Left, centre, and Right corridor points of the bridge are plotted as a spline.
3. Based on the number of segments, parameters are defined to place the generic Cross sections along the centreline corridor 3D polyline.
4. The parameters of the box girder are adjusted as desired by the user
5. To 'Left Lane width', 'Right lane width', 'Zleft' and 'Zright' Instance parameters are adjusted for each cross-section placed along the 3D polyline based on the Left and Right corridor points.
6. After the cross sections placed along the curve are 'Loft' to create a solid. The solid thus formed represents the as-cast geometry of the bridge.

Figure 14 shows the interface of as cast model generator module whereas Figure 15 shows the screenshot of the output of the coordinate exporter module.

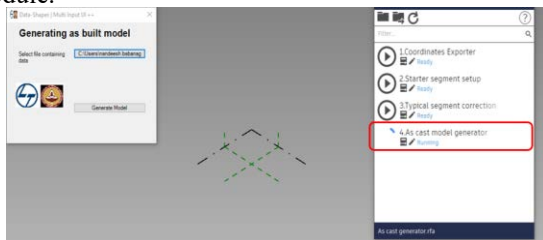


Figure 14: As-cast model generation module

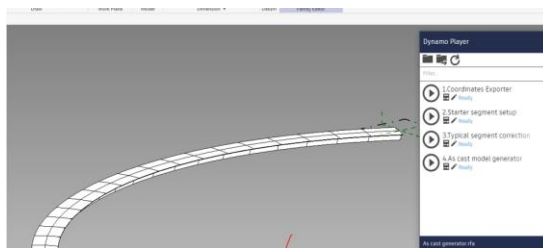


Figure 15: Output of As-cast model generator

4 Model Validation

The aim of the validation step in the current work was to determine the degree to which the suggested model for finding the corrected coordinates is close to the results obtained from a proprietary software used in a real-world project. The validation was performed in a user defined custom function which was developed using excel macro.

The comparison of the results obtained from the custom logic and proprietary software was made with respect to the global coordinate system, because of its ease of analysis. For testing the framework, first the site data of the planned coordinates and actual coordinates were obtained. The planned coordinates were input in both the custom application and MC3D software. The as-cast data of a segment is input in both MC3D and GEMBSC. The GEMBSC computes the corrected coordinates and hence the error in each segment for any error introduced assuming the corrected coordinates as the as-cast data for the downstream segments, but the MC3D requires inputs of the as-cast data at each step. The setup coordinates obtained from MC3D for each segment is entered as the as-cast data for the succeeding downstream segments.

The report of the global as cast joint coordinates are obtained from MC3D after the above step is repeated until the last segment. The coordinates obtained from the report are arranged in the required format to make the comparison. The results of validation are discussed in the following section.

5 Results

The following observations were made from the comparison of the outcomes of the validation steps.

Figure 16 shows an instance of the comparison for east side plan deviation. Similar plots were obtained for centerline plan, west side plan, CL elevations, and centerline alignment deviations.

The errors that occurred during casting of any segment were reduced in the succeeding segment/s and converged to zero after the casting of subsequent set of segments. However, with increase in the magnitude of the error the convergence took place over a greater number of segments. From this observation it can be inferred that the logic applied is effective, however the pattern of convergence may differ when compared to other methods of error correction.

It was further observed that the convergence of plan deviations made by MC3D is more rapid than the GEMBSC. In most cases, MC3D reduces the error in a single step. Whereas the custom software reduces errors in a more gradual manner, which is a more practical solution where the geometric constraints of the bridge are not violated. The same pattern is seen with respect to vertical alignment also.

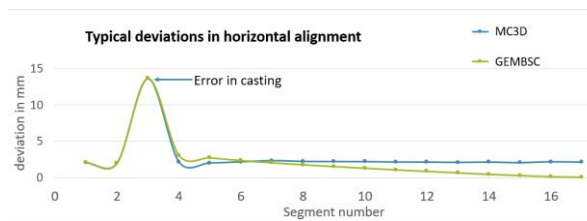


Figure 16: Plot typical deviation in horizontal alignment

6 Summary and Conclusion

In this work, a BIM-based application is developed for Geometric control of Short-line match casting of bridge segments. An algorithm for finding the corrected coordinates using the least square method is used in developing the application. The results from the solution algorithm was compared with the results of the commercially available software called MC3D. The GEMBSC gave better results as the error that occurred during the casting of any segment was corrected in the succeeding segments in a gradual manner with smaller corrections spread over a larger number of segments.

Future work could involve incorporation of 3D model creation with GEMBSC, that could be useful for quality management purpose through capturing data such as actual transverse pre-stressing force applied to the segment, date of casting of segment, the Engineer-in charge who conducted inspection, concrete strength used for the segment etc. Further, the application of linear actuators coupled with servos to adjust moulds, use of LiDAR based scanning methods coupled with BIM for automated data collection, and the use of Self-Propelled Modular Vehicle (SPMVs) needs exploration.

With the power of data analytics, the geometric control process can be explored to be made more proactive, by predicting the possibility of error based on various parameters and adjusting the moulds so as to nullify the errors.

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