constraints were discussed and incorporated into the model. The cranked system was rejected by the manufacturers on the basis that the joints were too complex. The design team then took the models of the twisted proposal and used them as the basis for their construction drawings for a mock up (figure 7.10).

Figure 7.10: Left and centre: facade unit mock up. Right: detail from parametric model.

7.3.3 Analysis

The process illustrates *translation* of a simple geometric procedure. MOS demonstrates generating alternatives as part of a narrow investigation where proposals were evaluated by specialists in terms of their construction logic. The parametric model was used to communicate design ideas to a manufacturer and demonstrate the possibility of construction. The case study illustrates a *rationalisation* procedure that implements a flat panel solution by taking advantage of tolerances in a framing system.

7.4 Gazprom Tower

7.4.1 Background

The design for Gazprom Tower (GAZ), proposed by architects RMJM consisted of a seventy five storey headquarters in St Petersburg for the Russian energy company Gazprom (figure 7.11). Parametric modelling was implemented during the design development stage, after a concept had been approved by the client. Facade design development had been subcontracted by RMJM to consultants Newtecnic. The author was engaged to support Newtecnic's design development process with parametric modelling. The parametric process was first concerned with the *translation* of geometric principles proposed by RMJM and *matching* the original design with a parametrically defined form. Newtecnic proposed a facade panelisation method, this too was captured parametrically and incorporated into the parametric model. The model produced geometry which formed the basis of drawings and visualisations which were used to assess the aesthetics of the tower. Analysis of the parametrically defined panelling system provided information for initial costing estimates.

Figure 7.11: Visualisation of Gazprom facades.

7.4.2 Overview of completed model

The geometry was defined with an adaptive floor plate. The method for a single floor can be considered as five squares arranged around a central point (figure 7.12 right). One edge of each of the squares is extended to the next square, the point of intersection defies a vertex of the floor edge. Repeating this for each of the squares defines a complete floor plate. The floor plate was translated upwards to define the next level. At each level the floor geometry was transformed, the squares rotate, scale about their local centres and the local centres translate radially from the floor centre point. This created a vertical set of individual floors which defined facades of twisted surfaces. Floor areas were recorded in spreadsheets and floor plans exported to individual model spaces within a single Microstation file.

The scaling, rotation and translation were controlled by graphically defined law curves (figure 7.12 centre). This graphical control allowed the parametric model to be closely matched to the original geometry by human interaction. Instructions from the architects would describe geometric changes in loose terms such as “can we make it a little bit fatter around floors forty-five to fifty-five”. The graphical control methods allowed an interactive soft approach for implementing these instructions.

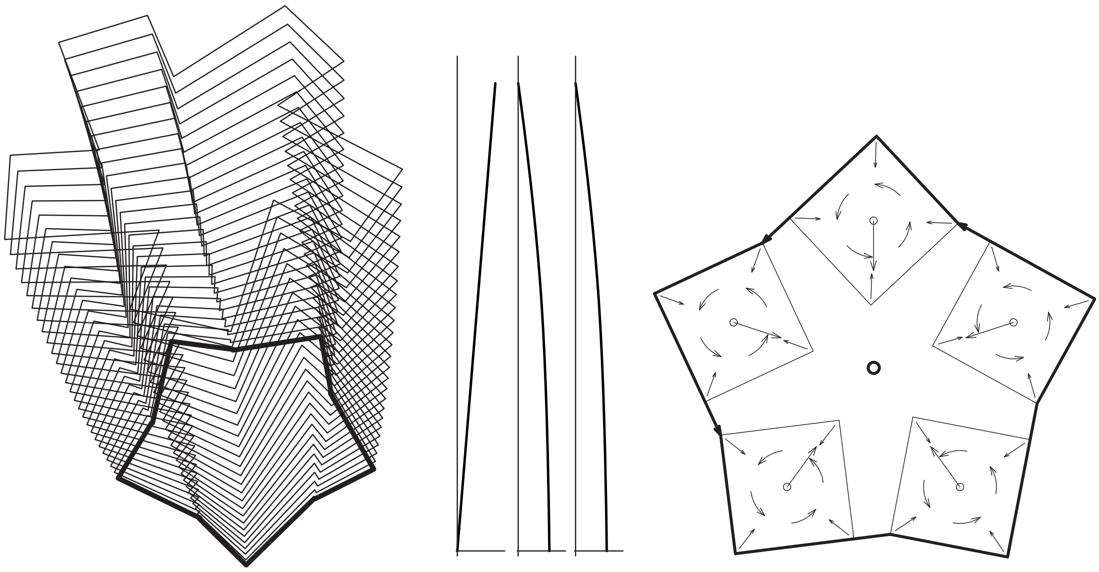

Figure 7.12: Gazprom tower. Left: floor plate variation. Centre: control curves for rotation, translation and scaling. Right: floor plate geometry.

The tesselation method proposed by Newtecnic was applied to the geometry defined by the floor plates in three-dimensions (figure 7.13 left) and in two-dimensions as unfolded elevations. The rotational symmetry of the tower defined five identical segments. Other than this rotational repetition, the twisting, scaling and translation of each floor level made each panel unique. Variation between some panels was very small and similar panels within tolerances could be identified. Panels were broken into two assembly types; a five sided unit and a four sided unit (figure 7.13 right top, heavy lines). Each contained a set of two or five triangular panels. Numeric data for each assembly type was extracted and compared to find panels which were identical within predefined manufacturing tolerances (figure 7.14). This identified groups of similar panels but many of these groups had few members. The cost of manufacture and construction of this number of non-repetitive elements was prohibitive for the design and subsequently the underlying geometry was altered to define more similar panel types.

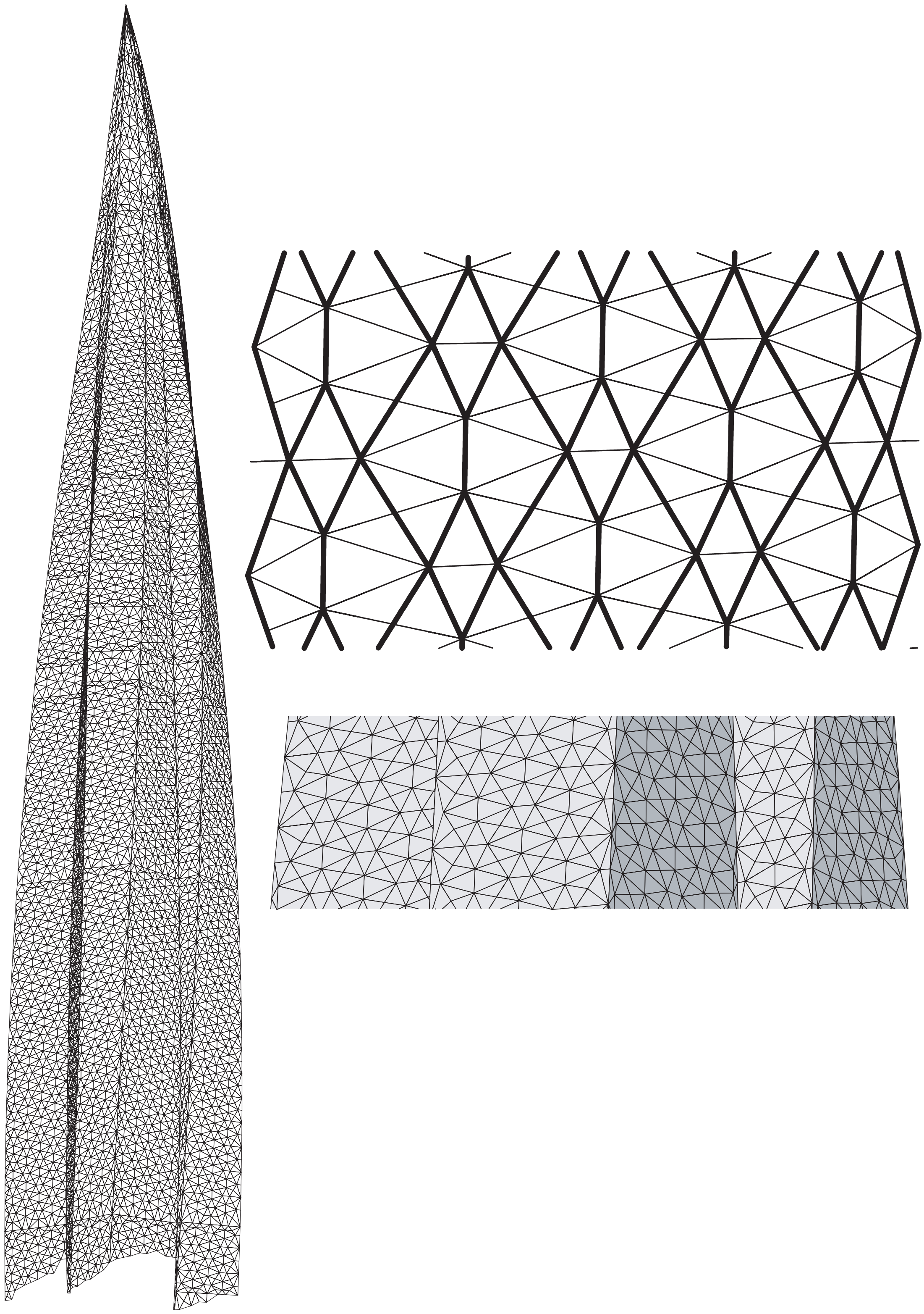

Figure 7.13: Gazprom geometry and panelisation. Left: full tesselation of Gazprom tower. Right top: assembly types (heavy lines) and panels. Right bottom: tesselation detail

NOTE: FIGURES REPRESENT ONE FIFTH OF BUILDING. ALL VALUES IN METRES SQ.

Assembly01				**Assembly02**			
TotalUnits	932			TotalUnits	476		
CountTypes	176			CountTypes	47		
TotalArea	8895.77			TotalArea	1900.63		
Types with 2 or less	106			Types with 2 or less	22		
UniqueCode	**TypeCount**	**TypeArea**	**TotalAreaForType**	**UniqueCode**	**TypeCount**	**TypeArea**	**TotalAreaForType**
6.15	168	10.64	1787.12	4.7	226	4.25	961.59
6.075	136	10.63	1445.01	4.725	33	4.26	140.67
6.1	70	10.63	744.36	6.7	30	4.26	127.66
6.175	35	10.64	372.29	6.375	23	1.89	43.58
			0.00				0.00
7.1	14	10.63	148.80	2.925	12	4.25	51.04
4.35	13	9.04	117.47	6.725	10	6.41	64.06
5.325	13	1.16	15.11	4.65	10	4.01	40.06
7.175	12	10.35	124.25	4.625	9	3.77	33.95
7.225	11	10.25	112.71	6.575	9	2.38	21.40
4.425	10	9.04	90.35	6.6	9	3.01	27.10
6.2	10	10.63	106.30	6.525	8	1.62	12.99
5.3	9	10.63	95.67	4.675	8	4.25	34.01
5.725	9	7.45	67.09	6.55	8	2.98	23.80
7.025	9	10.63	95.66	6.4	7	3.62	25.32
7	9	10.63	95.66	6.5	6	3.01	18.07
8.075	8	12.22	97.77	8.5	6	3.53	21.19
5.825	8	9.67	77.34	6.675	5	6.42	32.08
5.25	8	10.63	85.01	6.65	4	3.16	12.64
5.475	8	4.39	35.12	6.45	4	2.37	9.49

Figure 7.14: Grouping of panel types.

7.4.3 Analysis

The case study illustrates *translation* of geometric ideas in a process where the initial design idea already exists and the parametric task was to *capture design intent*, *match geometry* and *rationalise*. The design investigation was limited to studying a proposal for facade tesselation which was mapped onto an underlying geometric proposal. This involved defining detailed information on the number of panel types required for the proposed facade system and enabled *assessment of construction logic* and cost. Evaluation of this data later led to *rationalisation* of the underlying geometry to provide greater panel repetition.

Parameterising the proposed facade system provided the first opportunity in the design process to examine complete models of the facade. Prior to this the system had been considered too time intensive to model in a more traditional way. The parametric model provided the architects the opportunity to *assess the aesthetic* impact of the facade.

The case study indicated that graphical control methods could facilitate *translation* from verbal descriptions to geometric change. Requests from the architects for geometric change were expressed in loose descriptive language which could be interpreted by manipulating control curves until a satisfactory form was defined. GAZ is an illustration of a scenario where parametric modelling is undertaken by specialists external to the architectural design team. This corresponds with model described in chapter four, section 4.5 and illustrated in figure 4.25. This model offered the ability to work closely and share information directly with manufacturers. This was the case with this project. The model in chapter four, suggested separation between the architectural design team and the parametric modelling team could make translating design intent difficult. This proved to be the case with GAZ however the extent of these difficulties was lessened through the use of the graphical control mechanism.

7.5 Singapore Domes

7.5.1 Background

Singapore Domes (SING) case study consists of two domes (cool dry (CD) and cool moist (CM)) that enclose a cool dry and a cool moist ecosystem (figure 7.15). It is part of the Singapore Gardens in the Bay project (NationalParks, 2005). Construction began early in 2008 and completion is expected at the end of 2010. The domes are two similar designs, each is a composite structure consisting of a grid shell and a series of arches that are linked together by a series of tubular struts.

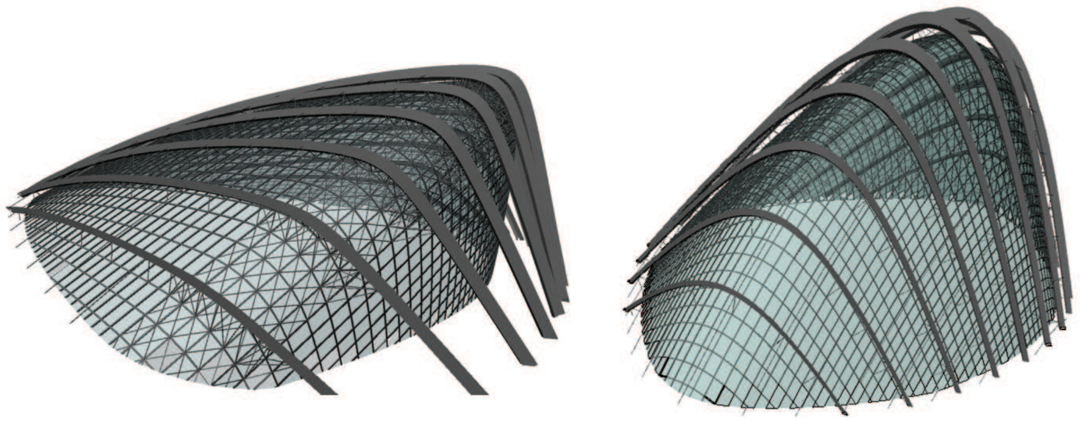

Figure 7.15: Singapore domes. Cool dry (left) and cool moist (right).

Architecturally the domes were designed by Wilkinson Eyre Architects (WEA), structural design was undertaken by Atelier One (A1). A1 employed Chris Williams (CW) and the author as independent consultants. Contractually A1 were responsible for structural design and communication of the geometry to the contractors. WEA had produced three-dimensional digital models as part of their design process. These models had been used for generating drawings and images of the domes. To improve the structural performance, geometrical changes were anticipated by A1. Manually remodelling geometry and redefining structural analysis files would have been too time consuming for the project time. A1 decided to pursue