Push Over: An artistic vision of concrete construction

Jedediah Martin¹, Sumit Anand¹, Simon Glaister², Jason Ingham³

ABSTRACT

An investigation was made into the relationship between modern seismic design in concrete, contemporary art and the current concern for social, economic and environmental sustainability, with the results displayed as an exhibition called Push Over at the St Paul Street Gallery in early August 2009. The project involved the reconstruction and simulated seismic testing of a beam-column joint element that lies at the heart of the gallery, supporting its ceiling and the Auckland University of Technology (AUT) Visual Arts building above. The remains of the tested element were then displayed in the gallery beneath the original joint. In this way an analogy was made between the notions of structural, cultural, and environmental collapse, and a direct connection drawn between our conception of the abstract art object – art as existing apart from life – and our encounters with the physical remains of failed cultures and societies – objects that have lost their world. The particular relationship between art, seismic design, and vulnerability assessment illustrated by this artwork is articulated here, and discussion pertaining to the many challengers resulting from laboratory testing in reinforced concrete at a 1:1 scale is provided.

1. INTRODUCTION

The idea of using large-scale architectural intervention in the production of avant-garde art has been with us since the beginning of the modernist period. However, the use of this technique to express and critique notions of entropy, anarchy and power began largely in North America at the end of the 1960's when artists such as Robert Smithson, Gordon Mata-Clark, and Chris Burden began producing the kind of work that would later come to be known as Post-Minimalism.

Three works from this period are of particular significance to this project: Smithson’s Buried Shed (1970), in which he buried an old shed at the University of Kent, Ohio, with the help of an excavator until the moment of its collapse [1], see Figure 1; Burden’s Samson (1985), which involved the installation of a 100-ton jack between the gallery’s walls driven by a turnstile at its entrance [2], see Figure 2; and Matta-Clark’s Splitting (1974), in which he cut a two storey suburban house in half [3], see Figure 3.

Figure 1: Robert Smithson’s ‘Buried Shed’ (1970) [1]

Figure 2: Chris Burden’s ‘Sampson’ (1985) [2]

Figure 3: Gordon Matta-Clark’s ‘Splitting’ (1974) [3]

Moving away from the sense of autonomy central to the Minimalism that preceded them, these artists began to concern themselves explicitly with the power and performative relationships between object, context, and audience. In doing so they also illustrated a simultaneous concern for the conflict between the forces of man and nature, self-destruction, internal instability and disaster, and it is with respect to these concepts that Push

1. Undergraduate research student, University of Auckland
2. Artist, Auckland University of Technology
3. Associate Professor, University of Auckland
Over both critiques and extends upon these historical models of art making, providing them with a new contemporary relevance.

2. VISION

2.1. Good Friday

Push Over was a site-specific sculptural installation exhibited at the St Paul Street Gallery, Auckland University of Technology, in August 2009. The work involved the full-scale reconstruction and simulated seismic failure of the beam-column element that sits at the heart of the gallery, and which supports its ceiling along with the AUT Visual Arts building above, see Figure 4. The reconstruction and subsequent simulated seismic failure of the element were undertaken in the Test Hall at the University of Auckland as part of a collaboration with the Department of Civil and Environmental Engineering. Following this, the element underwent a transformation from test piece to art object as it was transported from the laboratory to the gallery floor for exhibition next to the original column.

This project locates a wide range of different readings within a single object: It playfully critiques the authority of the museum within the avant-garde, the nature of authorship, and our obsession with the innovative and new in combination with ideas of structural entropy and collapse; it expands and extends upon historical models of art making; it critiques and contributes to a pre-existing dialogue within the New Zealand avant-gard; it comments directly on our society’s fascination with catastrophe; and it responds directly to the tectonic properties of New Zealand. However, for the purpose of this paper, its most relevant theme in a structural concrete context is a proposition regarding the origin and essence of both the museum and contemporary art object that, in conjunction with concepts from the field of vulnerability assessment, extends the relevance of this theoretical art discourse beyond the gallery, and into the world at large.

Figure 4: The beam-column joint located in the AUT St Paul Street Art Gallery, which is replicated in the project

2.2. Paradise Lost

Weltverlust is a German expression first used by Hegel in the early 19th century to describe what he saw as the defining character of the many objects of antiquity found in museums throughout Europe. Weltverlust, as he intended it, possessed two complimentary meanings. The first was an expression of these objects’ homelessness – a reflection of the way fate, “in delivering them to us, simultaneously withholds their world” [4]. As the material remains of past civilizations, objects of this type exist today in a state removed from the cultures and contexts that demanded them; abstracted from the systems of exchange and value that gave them their meaning, they are here, in this world, but no longer of it.

However, the very fact that these objects still mean something to us implies that their loss is in some way a positive aspect of our own world, and it is with respect to this curious fact that Hegel intends his second meaning of weltverlust – a longing or lust for world. As objects created by a community of people in the process of mutual self-realisation, these relics not only represent a particular way of life at a specific time and place, but also functioned as containers for the evolving feelings, thoughts, and worldviews of those who made and used them. Abstracted from the world of their creation they have been drained of this critical vitality and are now empty and static, yet they still contain a residue of this past importance, an imprint that demands to be heard and cries out for us to fill them once again. Just as we might long for what we have lost to the past, so too the past can long for what it has lost to us. Thus these objects, through the dual nature of their weltverlust, demand our care and attention, and while we cannot do as they request we nevertheless project upon them our own imagined approximations of the lives they once had in a process that only serves to reinforce the dislocation between their world and our own.

The home of this homelessness is the museum, where the objects’ weltverlust is best evidenced by the glass display case and balustrade [5]. While its stated purpose is to conserve any given object for prosperity (lust for world) it serves equally to reinforce the rupture between our world and that which it protects (loss of world) and in doing so, the very possibility that an object might be at once in this world but not of it – removed from our everyday reality – and still retain both value and meaning. In fact, since Hegel’s time the collections of museums have been defined almost solely by this dual property of weltverlust, and thus the museum is an institution created specifically for the care and consideration of what fate has delivered us. Furthermore, since Hegel’s
time and probably much earlier, objects have also been made expressly for the museum: a curious situation that lies at the heart of any separation between art and life as they are often discussed today.

### 2.3. Apocalypse Now

Central to this notion of weltverlust and the abstract object it implies is a kind of ‘end-of-the-world’. For us to encounter these objects so far removed from our own reality that any personal connection to the original modes of utility that gave them meaning is impossible, the worlds that created them must have ceased to exist. Indeed, history has shown us that civilisations are not immortal, and when studied as a group they display identifiable patterns of growth and decline – patterns that appear to be governed largely by a combination of initial conditions and systems of exchange that together imply a kind of capacity. When this capacity is reached a given civilisation will become unsustainable and, in the absence of significant change, collapse. However, a living culture is a constantly evolving, self-directed process that involves the continual assessment of anticipated demand (be that social, material, or environmental) in contrast with available capacity, and the modification of each such that the probability of demand exceeding capacity at any instant is kept below a perceived acceptable level of risk.

Such behaviour is analogous to the design of structures exposed to a seismic hazard. Within this field the intersection of demand and capacity – the analytical instant of failure – is known as the Performance Point [6], beyond which any assessed structure is predicted to fail. Further extension of this analogy might suggest the existence of a cultural Performance Point – an unforeseeable, but nevertheless existent point in the life of a civilisation beyond which it will undergo a rapid collapse. Interestingly, as a civilisation’s demands on its people and environment tend to increase with complexity, which itself appears to increase exponentially with time, thus this moment of collapse may occur amidst a period of great cultural prosperity or an apparent ‘golden age’ following recent years of accelerated progress. In this way, cultural collapse – though the direct result of identifiable patterns of human behaviour – can be as unexpected and violent as any natural disaster.

### 2.3. Revelations

*Push Over* then, represents in object form, the notion that the ongoing collection and preservation of the material remains of collapsed civilisations due to their weltverlust, has led to both the origin of the museum, and the essence of the contemporary art object as we perceive it today - a thing somehow abstracted from our everyday lives. *Push Over* suggest that the ontological foundations of the avant-garde are, in fact, grounded in our relationship to the material remains of once great and now collapsed civilisations, and that the abstracted art object (that which is made specifically for the museum or gallery – as was *Push Over*) is nothing more than an ancient ruin, reinterpreted and remade in a modern language.

However, what is of interest here is not just this inward looking and no-doubt incomplete hypothesis, but its surprisingly reflexive and expanding nature as can be seen: firstly, in the way that *Push Over* offers an image of the physical products of our own world as they may look in some distant future – or as that of the Classic Greeks, Romans, or Persians look to us today – and in doing so, presents as the object and content of the work the hypothesised origin and definition of both; and secondly, in the way in which current concerns regarding the continued sustainability of our own specifically Western way of life (be that due to cultural or environmental uncertainty or both), take this somewhat monastic model of the art object and expand its relevance out into society at large, only for that very expansion to flip back on itself and return to the rarefied world of art – but this time, like a mirror in the landscape, taking all the material products of our present reality with it.

### 3. PROCESS

#### 3.1 Design

Design of the original column installed at the St Paul Street Art Gallery was completed by Beca Consultants in 2002. Initially it was decided that the replica would be designed identical to the original construction, and so the as-built drawings were obtained from Beca and analyzed to establish reinforcement layout. It then became evident that the column was part of the gravity load system for the structure and thus the members framing into the joint did not exhibit reinforcement required in order to resist large seismic bending moments. To enhance the artistic appeal of the joint, it was required that a substantial amount of cracking be visible. This was not possible with an exact replica, thus it was proposed to perform a full ductile design of the joint with maximum cracking as the objective.
The major control factors of the design exercise were the capacity of the loading actuators, crane lifting capacity and the floor space available in the University of Auckland Test Hall. These constraints, in combination with the artist's perception of the joint, led to the unit being constructed of lightweight concrete with a 4.3 m column span and a 3.86 m beam span.

A design was drafted in accordance with NZS 3101:2006 [7] and the overstrength factor for the column was reduced to unity to increase cracking in the column. The amount of stirrups was increased to ensure that shear failure did not occur and instead a substantial amount of flexural cracking developed. The increased quantity of stirrups also provided additional confinement, which is a crucial requirement when using lightweight concrete. During the revision of this design a minor complication was faced: It was found that the contribution from the cover concrete was disregarded in strength calculations, which is a common exclusion when designing for seismic actions as the cover concrete tends to spall off. As an adverse effect to our project, the contribution of cover concrete increased the beam strength and therefore increased the necessary capacity of the loading actuators. The design also incorporated little actuator redundancy due to the large cross section geometry. To overcome this problem one longitudinal beam bar had to be removed from each side of the beam, which reduced the demand on actuators to well below their capacity. With the design finalised, an appropriate reinforcement schedule was drawn up and volume calculations were undertaken to determine the amount of concrete needed. The final detailing of the beam-column joint is shown in Figure 5.

3.2 Ordering Materials

Fletcher Reinforcing provided the reinforcement. The order consisted of 10 D25 longitudinal beam bars, 14 D25 longitudinal column bars and an appropriate number of R12 stirrups as per the construction details shown in Figure 5. The reinforcement was delivered to Stresscrete in Papakura, where construction was undertaken. One extra longitudinal bar and a few extra stirrups were also ordered to perform tensile testing in order to accurately determine material properties.

For the construction of the precast beam-column joint element an appropriate lightweight concrete mix design was required. Mr Sam Green (a recent
postgraduate student at the University of Auckland) had undertaken a Masters of Engineering thesis on the development of pumice lightweight concrete mixes [8] and was consulted for an appropriate mix design. This lightweight pumice concrete mix was reported to have a density of 1690 kg/m³ and a 28 day compressive strength of 30.5 MPa. Cement was ordered from Bridgeman Concrete and the pumice and other aggregates to be used in the mix were obtained from Winstone Aggregates.

3.3 Construction

Once all the appropriate materials had been ordered an area was set up for construction in the Stresscrete yard at Papakura. The first phase of construction involved assembly of the reinforcement, see Figure 6. A number of design flaws were revealed during this phase. When designing the stirrup spacing within the beam-column joint, allowance was not made for the extra width taken up by the stirrup bends, and appropriate space to allow insertion of a vibrator. The design stirrup spacing of 37.5 mm from centre to centre was not going to be achievable. Therefore, a decision was made to halve the number of stirrups in the joint region to give a final stirrup spacing of 75 mm from centre to centre. Although this decision reduced the shear capacity of the beam-column joint, because two longitudinal beam bars had been excluded from the original design, it was found that the shear demand in the joint had also been decreased. Hence, there were no adverse effects associated with the decision.

![Figure 6: Initial construction of the joint reinforcing cage](image)

Based on the artist’s requirement, plywood shutters surrounding the joint were constructed so that the beam-column ‘joint’ could be poured separately, see Figure 7. The intention of the separate pour was to create an appearance similar to the original concrete frame within the art gallery. However, this proved to be unfeasible in fitting, and a final decision was made to exclude these shutters and pour the beam-column joint as a single precast component.

![Figure 7: Applying plywood shutters to the joint region so that it could be poured separately](image)

After the plywood shutters were removed from the joint, the rest of the column longitudinal reinforcement was placed and the stirrups were moved into position and tied off. Once the column reinforcement was finally all tied off, another crucial error was discovered in the layout. It was found that the column cross section that had been tied was rotated 90 degrees from the orientation that was planned. This occurred because the unit was being constructed on its side, and therefore the cross section orientation differed from what was shown on the drawings. Once this mistake was identified, the column reinforcement had to be cut loose and retied. After some time and hard work the column reinforcement was located in its final position, where it was then again tied to the stirrups.

It was at this point that another minor discrepancy in the reinforcement cage was discovered. To construct the cage in the way chosen, (horizontally) it was required to support the side column bars directly on top of the side beam bars, see Figure 6. Thus where the side beams bars were tied, it became impossible to move them. This resulted in the side cover to the beam bar increasing to 75 mm, whereas the cover was designed to be 50 mm. As this was not found to change the lever arm in the axis of bending, it was decided that it should have minimal effect on overall strength.
With all of these problems overcome the final sets of stirrups were moved into position and tied securely, see Figures 8 and 9. Now that the cage was complete, it was stored to await placement onto the casting bed.

The next stage of construction involved cleaning and preparing the casting bed. This involved thorough grinding to remove bits of concrete, silicone and other construction material remaining on the bed from the previous cast. After much grinding, the dust and the loose material was hosed off with a compressed air outlet. Hence, the bed was ready for construction of the mould.

The mould was to be constructed of wooden shutters, using plywood and pine bracing. It was important for these shutters to have accurate geometry, so that there would be no gaps and associated spilling of concrete during the pour. Construction of these shutters was simple, involving nailing and screwing of the pine and plywood together, and the use of a nail gun made this process very quick and efficient. Even after considerable effort to avoid imperfections in the plywood, the nailing and screwing did leave holes and scratches on the mould face, which were covered over with builder’s bog and once dry, were sanded to give the required smoothness. Although attention to detail of this degree is rarely taken in regular construction, because the final structure was to be a piece of art, this detail was important.

The next step was to fix the shutters on the casting bed. The task was simple and involved laying the shutters in the desired location and fixing them into place using heavy duty magnets that attached themselves to the casting bed. However, minor curvatures in the shutters and the sliding on the slippery metal floor led to the joint region being deformed inwards during the first attempt. The whole setup was therefore pulled apart and reset, giving special attention to the inside cross section dimensions. Pieces of pine having a length of 600 mm, equal to the cross section width, were laid inside between the shutters at numerous locations. This helped to safeguard against any imperfections in the cross section width. In addition to the magnets, further pine and steel bracing was provided. Steel was welded to the bed and pine bracing installed around the structure to ensure that no deflection would occur when the concrete was poured. Chamfers were installed at appropriate locations and gaps filled with silicone at the end. Chamfers were also installed around the joint to give it a fake ‘separately cast’ look. Finally, the bed was blown out once more and oiled, making it ready for the cage, see Figure 10.

When the cage was brought down to the casting bed, a problem with the fitting was discovered. Only 25 mm of cover had been left at the end of longitudinal bars, which due to inaccuracies in tying the cage proved to be insufficient. A decision was made to saw cut and gas axe a further 25 mm off each of the bar ends, which provided the perfect opportunity to learn the use of new tools, see Figure 11. The performance of the joint was not comprised by this change.
The cage had to be supported on the bed with plastic bar chairs. A series of 35 mm chairs were fitted to the beam longitudinal reinforcement and 75 mm chairs were used to support the column reinforcement. This was found to give an overall distance to the centre of the reinforcement of 47.5 mm to the beam and 87.5 mm to the column. This differed from the design distance of 50 mm to the beam bars and 100 mm to the column bars. The difference was due to the method used to assemble the cage and the size of bar chairs available. As side distance is not critical in bending performance, the above values were accepted.

![Figure 11: The gas axe was used to remove 25 mm off the end of each longitudinal bar](image)

The cage was carefully lifted and lowered into place in the mould and a lifter was then tied into the reinforcement at the bottom end of the column to provide manoeuvrability once cast, see Figure 12. With the cage now fully in place it was time to place the concrete.

![Figure 12: The reinforcing cage with seats attached being lowered into the mould](image)

Bridgeman Concrete in Papakura were contracted to provide the lightweight concrete, with mix aggregates provided by Winstone Aggregates, see Figure 13. While mixing the concrete another design problem was encountered as Sam Green had only ever made 40 litres of the design mix, and it was not known how the mix would perform when made in larger volumes. Sam advised the team that extra water may need to be added due to high absorption of the pumice aggregate. While putting the mix together, the staff at Bridgeman Concrete realised that in fact the mix was far too dry. To overcome this, extra water and plasticising agent had to be added to the mix.

![Figure 13: Bridgeman Concrete batching plant in Papakura](image)

With the concrete now mixed and loaded into one of Bridgeman’s concrete trucks, it was transported to the Stresscrete yard. The concrete was then poured into a large hopper which was craned over the top of the concrete mould. A number of hopper loads of concrete were poured to fill the mould and while the concrete was being poured a vibrator was used to ensure adequate compaction of the concrete, see Figure 14. A series of four steel lifters were then placed on the top face at an equidistant from the centre of gravity of the structure to ensure easier lifting once the concrete hardened. Concrete test cylinders were also cast at the same time.

![Figure 14: Placement and compaction of concrete](image)

Finally, the top surface was trawled for an hour to obtain a slick, smooth finish of the hardened concrete. The structure was left to cure for three days after which it was deemed to have obtained...
sufficient strength, to be lifted from its mould. The mould was ripped apart and the anchors cleared in order to start lifting. The process is dangerous and was carried out carefully to ensure safety. Suction on the mould face and appropriate layout of the lifting chains had to be considered. The unit was lifted and placed in the yard, where it remained in storage until the testing date in mid July, see Figure 15.

Figure 15: The complete element is carefully removed from the casting bed

The following tasks are yet to be completed. The plans are briefly outlined.

3.4 Transportation to Laboratory

Transportation of the structure will take place during the week of 20th – 26th July 2009. Before transportation, the structure will have to be flipped over to reveal the mould face. This will be undertaken at the Stresscrete yard.

Crane and Cartage Limited of Manukau City have been contracted to transport the beam-column joint to the University of Auckland Test Hall using a large hiab equipped truck, shown in Figure 16. The beam-column unit will be lifted using the anchor at the column end and strops will be positioned equidistance from the centre of gravity to allow lifting. The hiab will then transport the test unit to the Test Hall.

At the Test Hall, dual action of the hiab and the in-house gantry crane will be required to manoeuvre the test unit. This will be done by lifting one end of the column with the hiab and the other column end with the crane. Also, skates will be used to manoeuvre the joint into final testing position.

3.5 Testing

Testing will be conducted during the week of 27th July - 2nd August 2009. The test set up is similar to the horizontal beam-column joint testing by Brooke [9], as shown in Figure 17. The two ends of the column will be restrained from lateral movement by large steel brackets bolted to the laboratory floor. Hydraulic actuators will be used at the column ends to supply an axial load, which will confine the column ends from deforming longitudinally. Two large hydraulic actuators with a 350 kN pull capacity will be fitted to the beam ends, as shown in Figure 17, and will work together to generate a series of cyclic deformations to the beams.

Figure 16: Truck used for transportation of the beam-column joint

Figure17: Testing layout employed in project [9]

Load cells will be fitted to the actuators to measure the force and potentiometers fitted to beam end to measure displacement, allowing the force-displacement history of the test unit to be recorded. Loading will be applied in terms of inter-storey drift, with the magnitude of the drift increased incrementally to achieve the degree of cracking as required by the artist. In conjunction with the testing, a number of tensile tests will be performed on the reinforcement and also the
concrete cylinders will be crushed to verify material strength.

4. EXHIBITION
Exhibition of the beam-column joint will be held at the AUT St Paul Street Art Gallery, opening in mid August 2009. It will be a solo exhibition with the damaged beam-column joint art piece being the only object on display. The damaged replica will be placed next to the original structure, and will remain in the gallery for a month, where it will be open for free viewing by the public.

6. CONCLUSIONS
A project which originated as an artist's ambition to capture aspects of structural, cultural, and environmental collapse, led to a journey that has opened doors for the concrete industry. The challenges of design exploited concrete's versatile properties; the process established industrial relations; and the exhibition will enhance public knowledge of concrete construction and its seismic performance. The success of the project was based on good faith and the generous contribution made by several entities. The project will hopefully be remembered as being iconic in the discipline of art and concrete construction.

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7. REFERENCES
6. Qiang X, A direct displacement-based seismic design procedure of inelastic structures. Civil and Hydraulic Engineering Research Center, Sinotech Engineering Consultants Inc, 171 Nanking East Road, Sec. 5, Taipei 105, Taiwan, ROC