ISSN: 2332-1091

Civil Engineering and Architecture

Volume No. 11

Issue No. 3

September - December 2023

ENRICHED PUBLICATIONS PVT. LTD

S-9, IInd FLOOR, MLU POCKET,
MANISH ABHINAV PLAZA-II, ABOVE FEDERAL BANK,
PLOT NO-5, SECTOR-5, DWARKA, NEW DELHI, INDIA-110075,
PHONE: - + (91)-(11)-47026006

ISSN: 2332-1091

Civil Engineering and Architecture

Aims and Scope

The subject areas include, but are not limited to the following fields:

- Architectural Drawing
- Architectural Style
- Architectural Theory
- Biomechanics
- Building Materials
- Coastal Engineering
- Construction Engineering
- Control Engineering
- Earthquake Engineering
- Environmental Engineering
- Geotechnical Engineering
- Materials Engineering
- Municipal Or Urban Engineering
- Organic Architecture
- Sociology of Architecture
- Structural Engineering
- Surveying
- Transportation Engineering

ISSN: 2332-1091

Civil Engineering and Architecture

Editor-In-Chief

Editorial Board

ISSN: 2332-1091

ISSN: 2332-1091

Civil Engineering and Architecture

(Volume No. 11, Issue No. 3, September - December 2023)

Contents

ISSN: 2332-1091

Experimental Evaluation of Bearing Capacity of Skirted Footings

S. Golmoghani-Ebrahimi, M.A. Rowshanzamir*
Civil Engineering Department, Isfahan University of Technology, Isfahan-Iran Corresponding Author: mohamali@cc.iut.ac.ir

ABSTRACT

Structural skirts have been used underneath shallow foundations of marine structures for many years, due to their stability advantages. However limited knowledge is available on the performance of the skirted foundations when it comes to their usage as conventional shallow foundations. In this research study the bearing capacity of such foundations was evaluated through laboratory testing. In this context the effects of skirt stiffness and depth on the bearing capacity of skirted footing models were investigated. The test results were then compared with various bearing capacity equations. It was found that using structural skirts may improve the footing bearing capacity up to 3.68 times depending on the geometry and structural specifications of the skirts and footings, soil characteristics and conditions of both soil-skirt and soil-footing interfaces.

Keywords Bearing Capacity, Skirted Footings, Shallow Foundations, Dense Sand

1. INTRODUCTION

The problem of bearing capacity of shallow foundations has been widely discussed in the geotechnical engineering literature. Till now numerous methods have been presented for determination of bearing capacity of foundations embedded in soils. Most of conventional methods are based on a limit equilibrium approach. Based on the limit equilibrium theory, a general shear mechanism is assumed within homogeneous soil underneath a strip footing. The footing bearing capacity is then determined based on static equilibrium of the soil wedge formed underneath the footing. Thus the amount of bearing capacity is directly dependent on the length of slip lines i.e. more lengthy slip lines yield greater bearing capacity. An increase in the length of slip lines may be achieved by increasing either the footing width or embedment depth (Das, 2007). Usage of structural skirts which encompass the soil underneath footing may also be a reasonable method to increase the length of slip lines (Figure 1 with B width of footing and Ds depth of skirt). Using this type of foundation may also reduce the cost of foundation construction as the amount of excavation and filling operations reduces for the skirted foundations in comparison to those of conventional foundations. Furthermore using peripheral skirts can prevent the soil beneath foundation from squeezing out and any damage due to excavations for adjacent construction works is minimized. Considering the potential advantages of skirted foundations, it seems using these foundations may make a great difference in the cost and performance of foundations. Meanwhile, more investigations must be carried out on the bearing capacity and settlement behavior of the skirted foundations to highlight their advantages for practicing engineers. Several research studies relevant to this subject will be reviewed in the following section.

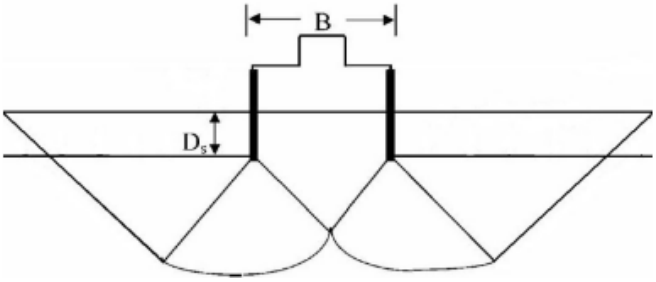

Figure 1. Increase in length of slip lines due to using of skirt

Bransby and Randolph (1998) and Hu et al. (1999) described the applications of marine skirted foundations and their computational methods in details. Bransby and Martin (1999) introduced a work-hardening model for performance of bucket foundations, under combined loading consisting of vertical, horizontal and moment components. They presented a method in combination with the analysis method of bucket foundations for jacket structures and validated it through centrifuge modeling. The results of centrifuge model tests were then compared with results of numerical analyses from which a good agreement was concluded between these results. Gourvenec (2002) studied the strip and circular skirted foundations on non-homogenous marine clay under combined loading using two and three dimensional finite element analyses.

Acosta-Martinez et al. (2008) reported the experimental results of a shallow skirted foundation under compression and tension loads. The foundation performance was considered under both permanent and transient loadings. Also the effects of consolidation stress level and stress history on foundation undrained bearing capacity and permanent load response were investigated. Gourvenec and Randolph (2010) examined consolidation beneath circular skirted foundations. They used small strain finite element analysis for quantifying fast and time dependent responses of circular skirted foundations under vertical single-axial loading. Foundations with frictionless boundaries and quite rough soil-skirt contact as well as various ratios of embedment depths to diameter were investigated and their responses were compared with those of shallow foundations. It was found that both embedment and boundary friction have major effects on the foundation consolidation response. Al-Aghbari and Mohamedzein (2004) proposed a modified bearing capacity equation for skirted strip foundations on dense sand based on the results of experimental study on skirted footing models. Several factors such as foundation base friction, skirt depth, skirt side roughness, skirt stiffness and soil compressibility were considered in this study and their effects incorporated in the bearing capacity equation. Based on their experimental studies they concluded that structural skirts can improve the foundation bearing capacity by a factor of 1.5 to 3.9.

Al-Aghbari and Mohamedzein (2006) studied the performance improvement of circular foundations using structural skirts through loading test models. It was found that this type of reinforcement increased the bearing capacity of base soil and improved the footing load–displacement response. Also it was found that the structural skirts reduce the settlement of surface footings compared with footings without structural skirts. At a bearing pressure equal to 50% of ultimate bearing capacity, the footing settlement reduced to about 11% that of footing without skirt. Al-Aghbari (2007) studied settlement of shallow circular foundations with structural skirts resting on sand. The experimental results showed that using skirted footing reduced the settlement of bed soil and improved the stress-displacement behavior of the footing. A settlement reduction factor (SRF) was proposed, which took into account various parameters effective on footing settlements. It was found that the use of structural skirts led to settlement reduction in the range of 0.1 to 1.0 depending on the applied load and skirt depth.

Nighojkar et al. (2010) studied the performance of bi-angle shaped skirted footing under two-way eccentric loads. They concluded that the differential settlement of extreme corners of the footing is affected considerably due to presence of skirts. Skirts have been found to be helpful in reducing differential settlement due to eccentric loading.

As noted above, most of previous studies were devoted to skirted foundations for marine structures. Although some experimental studies focused on strip skirted footings as conventional foundations, they involved only with partial peripheral skirts. This paper reports the results of an experimental study on the performance footing models with full peripheral skirts in various conditions.

2. TESTING SETUP AND MATERIALS

Loading tests were performed on skirted model footings embedded to sand in a test box encased within a rigid steel frame. Regarding to the span of available loading frame, a test box with interior size of 440×420×450 mm was selected. The test box consisted of a steel rigid floor and two wooden sides with metal braces, while other sides were built of 10mm thickness Plexiglas with steel bar supports, to prevent them from lateral expansion. The internal faces of wooden sides were covered with a thin layer of smooth plastic to prepare it for lubrication. To minimize boundary friction, all of the internal faces of side walls were greased and left for at least one hour to allow the uniform spreading grease over the surface (Yung et al., 2004). Model footings of 70mm width were adopted based on the box dimensions to avoid of rigid walls effects on the footing bearing capacity (Bowles, 1996; Salençon, 2002). The footings were made of aluminum plates which their typical specifications are shown in Figure 2. Each skirted footing consisted of a rigid base with more than 25mm thickness and a skirt made of aluminum plate shaped as box profile. The rigid footing could be fixed to the skirt by several proper screws during the model placement in the sand. To maintain plane strain condition within soil underneath the model footing, the box width was limited nearly to the size of the footing length using two steel profiles of 80mm width. In such a condition each end of the footing is located at near adjacent of the steel profile and prevents soil displacement in the longitude direction. Thin lubricated films were placed at the contact surfaces of the footing ends and the steel profiles to eliminate friction at their interfaces.

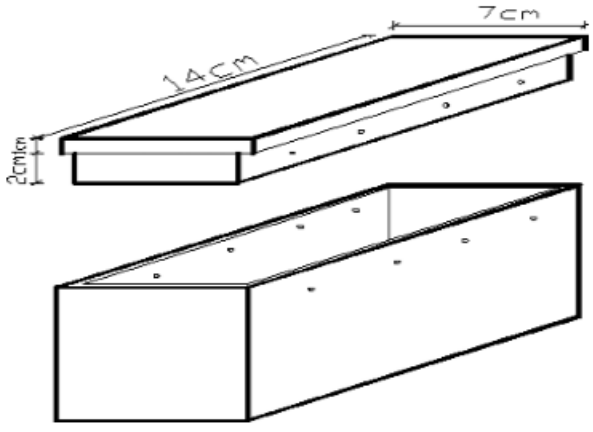

Figure 2. Specifications of Skirted Footing Model

2.1. Materials

A sandy soil was used in this experimental investigation.

The grading curve of this sand is shown in Figure 3. The sand grading characteristics D10, D30, D60 were determined 0.25, 0.47, and 0.85mm respectively. These yielded uniformity coefficient, Cu, 3.2 and

curvature coefficient, Cc, 1.04. Thus the sand was classified as uniform or poorly graded sand, SP, based on unified soil Classification system.

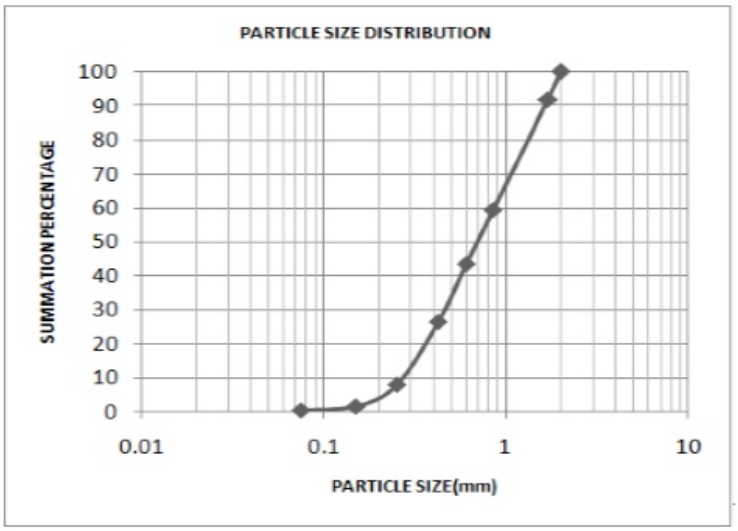

Figure 3. The grading curve of used sand

The specific gravity of the sand was measured 2.7. The minimum and maximum dry unit weights of the soil were obtained as 16.28kN/m3 and 18.69kN/m3 respectively. Using sand raining technique a medium dense state was achieved at unit weight of 17.67kN/m3 which equals to relative density of 61%. Achievable density in this technique depends on the precipitation intensity and uniformity of sand rain as well as height of fall (Cresswell et al., 1999). The test density was achieved when the sand spilled within the test tank at flow rate of 22g/sec through a funnel from constant height of 20cm.

The strength properties of the sand were determined through direct shear tests. These tests were carried out at normal stresses 39, 54.76 and 86.22kPa on 63mm diameter samples at shear displacement rate of 1.06mm/min. The average value of peak friction angle of the sand was found to be 42º. In footing load tests proper sand paper was glued to inner and outer sides of skirt as well as bottom face of footing to provide rough contacts with sand. Friction angle between the test sand and the abrasive paper was determined 36º over the same normal stresses using the direct shear apparatus. This value of contact friction angle is approximately equal to the friction angle between concrete and soil ($\delta \approx 0.9\varphi$) and this may simulate the conditions of real foundations.

2.2. Test Procedures

Enough sand height was required to avoid of likely effects of rigid bottom of test box on the footing bearing capacity. Thus several loading tests on a typical model footing were carried out at various cases of sand layer height within the test box. The test results in terms of the footing bearing capacity versus the sand height have been shown in Figure 4. These results showed that for sand thickness greater than 4B the footing bearing capacity sympathized nearly to a constant value (B; width of model footing). Thus the sand fill of 4B height was placed within the test box to omit any effect of the box rigid bottom on the footing bearing capacity.

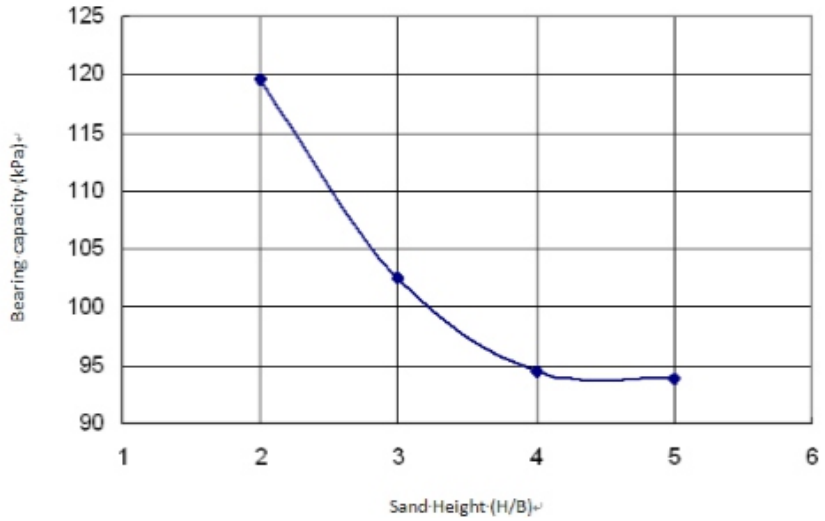

Figure 4. Footing Bearing Capacity versus the Relative Sand Bed Thickness on Rigid Base

To carry out each loading test, all internal faces of the test box walls were properly lubricated. The box was then placed within the loading frame of the triaxial apparatus and filled with sand. The sand placement was made by sand raining technique to reach the required height of 4B and its top surface was leveled gently by a light thin ruler. The footing skirt was then placed centrally across the width of the box. The sand raining continued simultaneously into the skirt and the test box to the level predicted for footing base. After leveling the sand surface within the skirt, the base was carefully fixed on the skirt by 8 screws. The model footing was then subjected to centric vertical loading using a displacement control apparatus at rate of 1 mm/min. The applied load was recorded by a 30kN proving ring with precision of 10N at every 0.5mm settlement. Figure 5 shows various stages footing placement into sand bed and loading test. Repeatability of tests was also considered and although the difference in the results were mostly less than 5%, the mean values of three replications of each test were employed to achieve more accurate results.

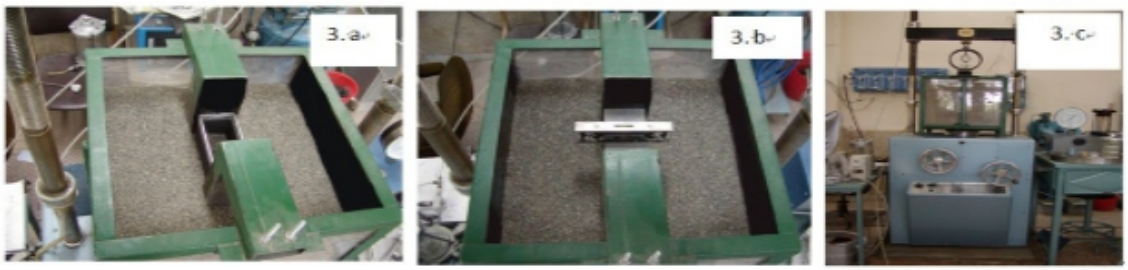

Figure 5. Test Preparation Sequences; a) Skirt Placement, b) Matching Base Footing, c) Load Application

3. RESEARCH RESULTS

3.1. The Effect of Skirt Thickness

To investigate the effect of structural skirt's thickness on the bearing capacity of the skirted footings, three types of skirts with 1, 3 and 5 mm thickness were selected. The embedment depth of the skirted footing for these testing cases was selected as 1B which corresponds to a depth ratio of D/B=1. The skirted footing was then subjected to displacement control loading and the applied loads were recorded from a dial gauge at 0.5mm settlement increments. Figure 6 shows the stress-settlement relationship for

the skirted footings with various thicknesses of structural skirts. As it is evident from Figure 6, stress-settlement curves of the footings with 3 and 5mm skirt thickness were matched well with each other, and show nearly the same ultimate bearing capacity and slope trend, while the load bearing curve of footing with 1mm skirt thickness was different. The stress-settlement curve for 1mm skirt thickness footing follows initially the same path of other curves but shows much lower slope changes than the other curves at high settlements. Furthermore unlike the two other curves, the slope change occurs smoothly so that no distinctive discontinuity point may be determined in this case. In fact, the stress-settlement curve of 1mm skirt thickness footing passes smoothly through the break point of the curves of 3 and 5mm skirt thickness footings, and shows greater bearing pressure at high settlement values. This may attributed to the lateral expansion of the 1mm thick skirt at high stress levels. This lateral expansion is associated with an increase of foundation width at bottom level of skirt and thus bearing pressure shows a linearly increasing trend.

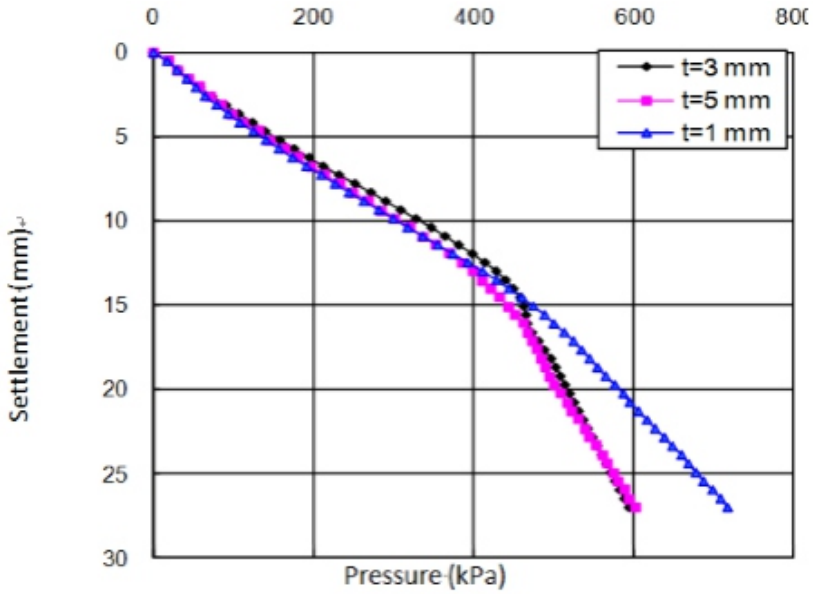

Figure 6. Pressure-Settlement of Skirted Footing for Various Skirt Thicknesses

2.1. Effects of Embedment Depth

In this section the effect of embedment depth of skirt on the bearing capacity of model footings was investigated. Several loading tests were carried out for different skirt dept ratios (D/B) of 0.5, 1 and 1.5. The test procedures were the same as described in previous section. It should be mentioned that, in all cases, for preventing the rigid base effects on the tests results, the test box was filled with sand to the height of 4B (280mm) and the skirt was then placed on the leveled surface of sand. The stress-settlement data obtained from these tests are presented in Figure 7. All of the pressure-settlement curves show nearly the same initial slope but involve different failure point from which the footing settlement increases linearly at a relatively high slope with pressure increase. The pressure failure point (the pressure corresponding to discontinuity point at pressure- settlement curve) was determined as the footing ultimate bearing capacity. The ultimate bearing capacity values and corresponding settlements have been presented in table 1 for the model footings. Figure 8 shows the variations of the footing ultimate baring capacity versus the skirt depth ratio $\left(\frac{D}{B}\right)$. . As it is seen, this relation is non-linear i.e.

with more pèronøounced increasing effects on bearing capacity at higher depth ratios. In fact, the rate of increase in the bearing capacity due to increasing depth ratio from 1 to 1.5 is much higher than that

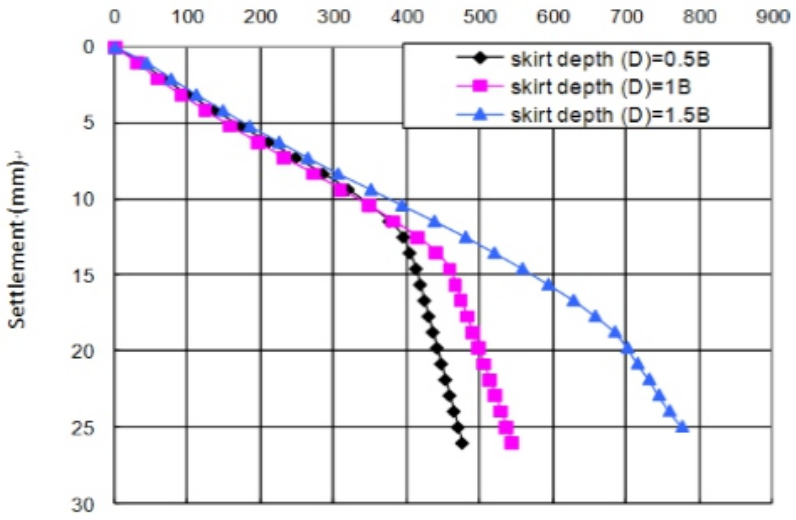

Figure 7. Pressure-Settlement of Skirted Footing for Different Depth of Skirts

Table 1. Bearing capacity and settlement of strip skirted foundations with different height of skirts

Skirt height	q_{ult} (kPa)	Failure Settlement (mm)
0.5 B	388	12
1 B	463	15
1.5 B	685	18.5

3.3. Comparison with Conventional Methods

Bowles (1996) introduced four sets of ultimate bearing capacity equations as the most popular methods for foundation design calculations. These methods are included of Terzaghi (1943), Meyerhof (1963), Hansen (1970), and Vesic (1973) methods. All of these methods are based on limit equilibrium theory with some differences in their assumptions regarding slip surfaces and loading conditions.

Here, the ultimate bearing capacity of shallow foundations with the same embedment depth as the skirt height was calculated using the conventional methods. An improvement ratio was then determined as the ratio of the experimentally determined ultimate bearing capacity of the skirted model footings to the calculated value of ultimate bearing capacity of foundations with the same embedment depth. The values of the improvement ratio for various embedment ratios are presented in table 2. It is clearly observed that using of skirt in the model footings was more effective than embedding the foundations in the same depth of skirts height. The improvement ratio of bearing capacity was averagely ranged from 2.91 to 3.68 depending on the embedment depth. Comparing with previously reported improvement ratios of 1.5 to 3.9 (Al-Aghbari & Mohamedzein), the least improvement ratio for the new skirt conditions (full peripheral skirt instead of partial skirt) showed an enhancement of nearly twofold. The results also showed that using skirted footing had the greatest efficiency at embedment ratio of 0.5. Figure 8 presents the variations of the ultimate bearing capacity of the model footing versus the embedment depth (or skirt height) from the conventional methods along with those of the experimental results. Again it is interesting to see from Figure 8 that the skirt depth has considerable effect on the footing bearing capacity in comparison with the embedment depth of conventional foundations.

Furthermore, the experimental results showed that the ultimate bearing capacity increased nonlinearly with the skirt depth while the bearing values from conventional equations had an approximately linear increase with the embedment depth for the considered depth ratios.

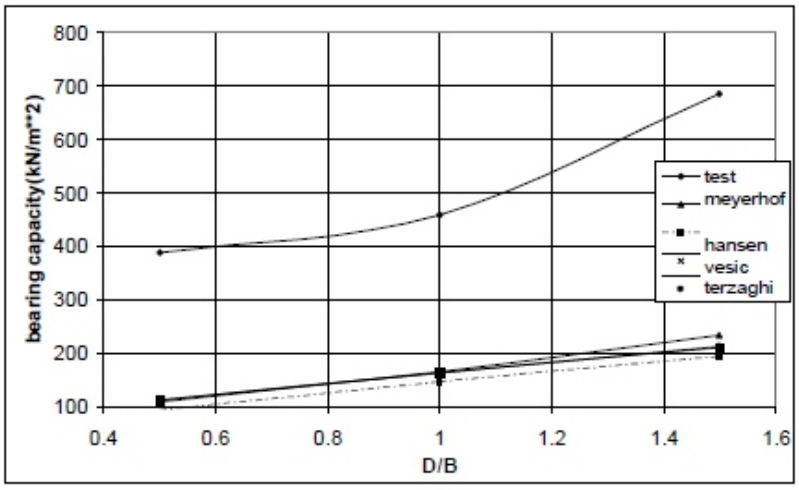

Figure 8. Variation of Bearing Capacity versus Skirt Depth Ratio

Table 2. Improvement ratio of bearing capacity using the structural skirt

	D/B=0.5	D/B=1	D/B=1.5
Terzaghi	3.46	2.85	3.22
Meyerhof	3.59	2.78	2.93
Hansen	4.18	3.19	3.55
Vesic	3.48	2.83	3.24
Average	3.68	2.91	3.24

4. CONCLUSIONS

The performance of skirted footing models in sand was investigated under vertical loading. The consideration was focused on the effects of skirt thickness and embedment depth on the footing bearing capacity and the following conclusions was made based on the obtained results:

1. Using peripheral structural skirt in combination with conventional footing improves the overall foundation performance in terms of increasing bearing capacity, lowering excavation volume, and encompassing the soil underneath footing.
2. Footing with flexible skirts showed greater bearing capacity at high settlement values while for rigid skirts (thickness above 3mm) the skirt thickness had no significant effects on the footing bearing capacity.
3. Skirting the model footings was found to be more effective than embedding the foundations in the same depth as skirts height.
4. The ultimate bearing capacity of the skirted footing was 2.91 to 3.68 times greater than the average value of the calculated ultimate bearing capacity of foundations with the same depth as skirt depth. For the new skirt conditions (full peripheral skirt lieu of partial skirt), the least improvement ratio showed an enhancement of nearly twofold (from 1.5 to 2.91).

ACKNOWLEDGMENTS

The authors thank the Isfahan University and Technology for financial support.

REFERENCES

[1] Das, B.M., 2007, Theoretical Foundation Engineering, Originally published: Amsterdam, Elsevier Science c1987.

[2] Bransby, M.F., and Randolph, M.F., 1998, Combined loading of skirted foundations, Geotechnique, Vol. 48, No. 5, P.P. 637-655.

[3] Bransby, M.F., and Randolph, M.F., 1998, The effect of skirted foundation shape on response to combined V-M-H loadings, Proceeding of the International Offshore and Polar Engineering Conference, Vol. 1, P.P. 543-548.

[4] Hu, Y, Randolph, M.F., and P.G., Watson, 1999, Bearing response of skirted foundation on nonhomogeneous soil, Journal of Geotechnical and Geoenvironmental Engineering, Vol. 125, No. 11, P.P. 924-935.

[5] Bransby, M.F., Martin, C.M. 1999, Elasto-plastic modeling of bucket foundations, NUMOG VII International Symposium on Numerical Models in Geomechanics, Netherlands, A.A.Balkema, P.P. 425-430.

[6] Gourvenec, S, 2002, Combined loading of skirted foundations, Proc. ANZ YGPC Rotorua, New Zealand, Ed Davies, P.P. 105-110.

[7] Acosta Martinez, H.E., Gourvenec, S.M., Randolph, M.F., 2008, An experimental investigation of a shallow skirted foundation under compression and tension, Soil and Foundations, Vol. 48, P.P. 247-254.

[8] Gourvenec, S., Randolph, M.F., 2010, Consolidation beneath circular skirted foundations, International Journal of Geomechanics, Vol. 10, art. No 003001QGM, P.P. 22-29.

[9] Al-Aghbari, M.Y., Mohamedzein, Y.E.-A. , 2004, Bearing capacity of strip foundations with structural skirts, Geotechnical and Geological Engineering, Vol. 22, No. 1, P.P. 43-57.

[10] Nighojkar, S., Naik, B., Pendharkar, U., Mahiyar, H., 2010, Performance Study of Bi-Angle Shape Skirted Footing in Yellow Soil Subjected to Two-way Eccentric Load, Proc. of Int. Conf. on Advances in Civil Engineering, P.P.101-106

[11] Al-Aghbari, M.Y. , 2007, Settlement of Shallow Circular Foundations with Structural Skirts Resting on Sand, The Journal of Engineering Research Vol. 4, No.1 , P.P. 11-16

[12] Al-Aghbari, M.Y. and Mohamedzein, Y.E. (2006) "Improving the Performance of Circular Foundations Using Structural Skirts", Journal of Ground Improvement, Vol. 10, No.3, pp. 125-132.

[13] Salençon, Jean, 2002, "The influence of confinement on the bearing capacity of strip footings", C.R.Mecanique 330, P.P. 319-326.

[14] Bowles, J.E., 1996, Foundation analysis and design, 5th ed., McGraw-Hill Publishing.

[15] Yung, S.F., Tesang, J.C., Holtz, R., Wai, F.L., 2004, Reduction of boundary friction in model tests, Geotechnical Testing Journal, Vol. 27, No. 1, P.P. 312.

[16] Cresswell, A. , Barton, M.E. , Brown, R., 1999, Determining the maximum density of sands by pluviation, Geotechnical Testing Journal, Vol. 22, No. 4, P.P. 324-328.

[17] Terzaghi, K., (1943) "Theoretical Soil Mechanics", John Wiley & Sons, New York, 510pp. (as cited by Bowles, 1996).

[18] Meyerhof, G. G. (1963), "Some Recent Research on the Bearing Capacity of Foundations" CGJ, vol. 1, no. 1, Sept, pp. 16-26. (as cited by Bowles, 1996).

[19] Hansen, J. B. (1970), "A Revised and Extended Formula for Bearing Capacity" Danish Geotechnical Institute, Copenhagen, Bul. No. 28, 21 pp. (successor to Bul. No. 11), (as cited by Bowles, 1996).

[20] Vesic, A. S. (1973), "Analysis of Ultimate Loads of Shallow Foundations" JSMFD, ASCE, vol. 99, SM 1, Jan, pp. 45-73. (as cited by Bowles, 1996).

ISSN: 2332-1091

Laboratory Investigation on the Short-Term Compressive Strength of Microbial Laterized Concrete

Awolusi T. F., Akinkurolere O. O., Oke O. L.*, Adetifa O. A.
Civil Engineering Department, Faculty of Engineering, Ekiti State University, Ado-Ekiti, Ekiti State, Nigeria *Corresponding Author: seyioke@hotmail.com

ABSTRACT

This study investigates the effect of Bacillus subtilis JC3 on the compressive strength of laterized concrete. Taguchi method of experimental design which involved the use of orthogonal tables with three levels and three factors was employed. In all, 108 samples of 150mm×150mm×150mm concrete cubes cured in two media (water and nutrient broth) with a mix ratio of 1:2:4 were tested for compressive strength at 7, 14 and 28 days. The factors used were water/cement ratio, percentage laterite replacement for fine aggregate and concentration level of bacterial medium (added in different proportions as liquid for mixing the composite material). The results showed that Bacillus Subtilis JC3 generally enhanced the compressive strength and durability of the conventional concrete studied. The observed optimum values for water/cement ratio and bacterial medium for the constitution of concrete were found to be 0.50 and 20% respectively, however a negative trend was observed for laterite replacement for sand.

Keywords Compressive Strength, Water/Cement Ratio, Laterite, Sand, Granite And Bacillus Subtilis JC3

1. INTRODUCTION

Concrete is a composite material containing - cement, aggregate and water which are added in different proportions based on the desired use. The aggregate is generally coarse gravel or crushed rocks such as limestone, or granite, along with fine aggregate such as sand. Portland cement is commonly used as binder and various chemical admixtures such as fly ash, silica fumes and ground granulated blast furnace can also be added to produce concrete with improved strength and durability [1].

Due to increasing cost of producing concrete using these conventional materials such as cement, river sand as fine aggregate and granite as coarse aggregate in Nigeria, researchers have been working on alternative, cheap and readily available materials that would serve perfect substitutes for such materials while still meeting the set requirements for concrete in the industry. The use of laterite in combination with river sand in particular have received much attention in Nigeria, laterite being a tropical soil that is abundantly available in the tropical belts of the world. This had attracted the interest of researchers both in the time past and in recent times [2-9]. The efforts of these researchers have led to the production of laterized concrete. Salau, [10] defined laterized concrete as concrete in which stable laterite replaces fine aggregate, basically sand. Results of investigations on laterized concrete as reported by most researchers have consistently shown that laterized concrete is inferior in compressive strength and durability when compared to conventional concrete. For this reason, laterized concrete has found little or no application in the Nigerian construction industry.

Generally in the preparation of concrete, the addition of water to its dry constituents brings about chemical reaction between it and cement which is referred to as hydration thereby producing cement gel and Calcium Hydroxide (Ca(OH)2). From these products of hydration, Ca(OH)2 most readily react

with Carbon IV Oxide (CO2) to form Calcium Carbonate (CaCO3) with the rate of carbonation of concrete increasing with an increase in concentration of Co2 Carbonation could have some positive consequences because CaCO3 occupies greater volume than Ca(OH)2 which it replaces and in turn reduces the porosity of concrete since it is generally accepted that the durability of concrete is related to the characteristics of its pore structure [11]. An alternative means of making more CaCO3 available to fill more concrete pores is the use of Microbiologically Induced Calcium Carbonate Precipitation (MICCP) resulting from the metabolic activities of some specific micro-organisms embedded in concrete thereby increasing its compressive strength and overall durability.

With recent encouraging reports on compressive strength enhancements achieved in conventional concrete through Microbiologically Induced Calcium Carbonate Precipitation (MICCP), it is envisaged that if such measure is introduced to laterized concrete, its compressive strength could possibly be pushed to a level good enough for various applications in the construction industry. The present work therefore assesses the compressive strength of laterized concrete under the effect of Bacillus Subtilis.

2. MATERIALS AND METHODOLOGY MATERIALS

The materials used for this experiment were:

- Cement
- Fine Aggregate (Sharp Sand)
- Laterite
- Coarse Aggregate (granite)
- Water
- Nutrient Broth
- Bacillus subtilis JC3 (Bacteria)

2.1. Cement

The cement used for this experiment was the Ordinary Portland Cement (OPC) produced by Dangote Cement Company. This met the requirements of BS 12 [12].

2.2. Fine Aggregate

Fine aggregates used (sharp sand and laterite) were locally obtained. The gradation curve of the laterite used is as shown in Figure 1.

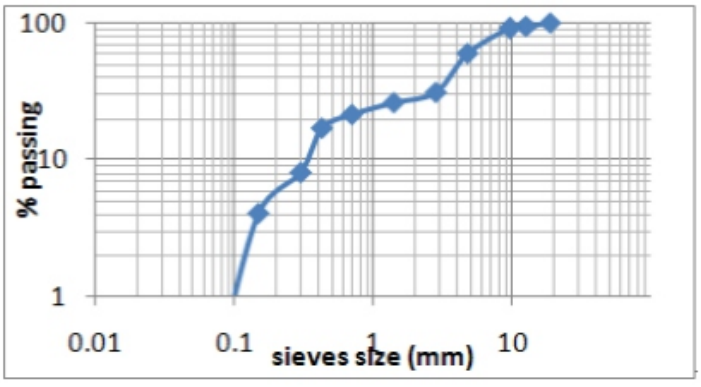

Figure 1. Sieve Analysis for Laterite

The coefficient of uniformity of the laterite used was 15.15 which classified the material as well graded.

2.1. Coarse Aggregate
Crushed angular granite from local quarry was used as coarse aggregate in this investigation.

2.2. Water
Tap water (potable) was used for mixing and curing during the laboratory investigation.

2.3. Nutrient Broth
Biomark nutrient broth commercially available was obtained in a chemical and laboratory equipment shop and used for the laboratory investigation..

2.4. Bacteria
Pure cultures (Bacillus Subtilis JC3) were maintained on nutrient agar slants which form irregular dry white colonies on nutrient agar. Whenever required a single colony of the culture was inoculated into nutrient broth of 25 ml in 100 ml conical flask maintained at a temperature of 370C and placed in 125 rpm orbital shaker. Growth was stopped after 48 hours when the concentration of bacteria reached 105 cells/ml and was preserved at a temperature of 50C until further use. Reddy et al [13] in their work achieved highest compressive strengths using bacteria concentration of 105 cells/ml from a wide range of experimented values.

3. Design of Experiment
In this work, Taguchi's approach of experimental design was adopted in order to reduce the number of trials required to gather necessary data. An orthogonal array L9, 3 series (as shown in Table 1) was used. The three levels considered which formed the column of the orthogonal array were the water/cement (w/c) ratios - 0.45, 0.50 and 0.55, while the test factors on the orthogonal rows considered were the percentage replacement of fine aggregate content with laterite (LAT), the water /cement ratio (W/C) and the changes in the volume of Bacterial medium (BM) which depends on the quantity of water required for each run respectively as shown in Tables 2 and 3 [14].

Table 1. Summary of Test Factors and Levels for OA L_9

Level	Factors		
	W/C ratio	Laterite Content	Bacterial medium
1	0.45	0%	10%
2	0.5	20%	20%
3	0.55	40%	30%

Table 2. A Three Level Orthogonal Array (L_9 [3 series])

Trial No	Water / Cement ratio	Laterite Content (%)	Bacterial Medium (%)
1	1	1	1
2	1	2	2
3	1	3	3
4	2	1	2
5	2	2	3
6	2	3	1
7	3	1	3
8	3	2	1
9	3	3	2

Table 3. Proportion used for the various Mixes

Test No	Water / Cement Ratio	Laterite Content (%)	Bacterial Medium (%)
1	0.45	0	10
2	0.45	20	20
3	0.45	40	30
4	0.5	0	20
5	0.5	20	30
6	0.5	40	10
7	0.55	0	30
8	0.55	20	10
9	0.55	40	20

4. COMPRESSIVE STRENGTH TEST

To study the compressive strength of laterized concrete, Bacillus sp. JC3 was grown in Nutrient broth medium. The concrete mix ratio was 1:2:4 (batching done by weight), and the bacterial culture/water to cement ratio was varied at 0.45, 0.50 and 0.55 respectively. A cube mould of 150 mm was used. The mixing of concrete constituents was carried out with materials being laid in uniform layers, one on the other in the order–coarse aggregate, fine aggregate and cementitious material. Dry mixing is done to obtain a uniform colour. Required amount of bacteria medium was added along with the water. Cubes were cast and compacted with a vibration machine and left in the molds for 24 hrs before de-molding. After de-molding, all specimens were weighed as shown in Figure 2 and cured in water and Nutrient broth medium at room temperature until the time of test. Control specimens were also prepared in similar way where water was used for mixing. Compression testing was performed as shown in Figure 3 using PACER Automatic Compression Testing Machine.

Figure 2. Weighting of a cube sample

Figure 3. Crushing of a Sample in a Compression Machine

5. RESULTS AND DISCUSSION

The crushing load of concrete for each curing medium was obtained after 7th, 14th and 28th days of curing and the average crushing load was obtained by the addition of the crushing load for each variation and divided by the total number of cubes of the variation in concern respectively.

Table 4 gives the compressive strength at 7 days, 14 days and 28 days for different water cement ratios of 0.45, 0.50 and 0.55 for control concrete, while Tables 5 and 6 present the summary of compressive strength of laterized concrete at 7 days, 14 days and 28 days for concrete cured in water and in nutrient broth medium for test numbers 1 to 9. From these tables, it is observed that the compressive strength of concrete for test number 4 with no laterite as aggregate showed a significant increase of 20% and 41% for concrete cured in water and nutrient broth medium respectively at 28 days in comparison with control concrete while test number 5 with 20% laterite replacement gives an increase in compressive strength of 9.6% and 22% for concrete cured in water and in nutrient broth medium respectively at 28 days in comparison with control concrete. The Taguchi method gives a clear picture of the importance of each of these factors as shown in Tables 7 and 8. The orthogonal analysis on compressive strength of microbial laterized concrete with the average effect of each of the factors - W/C, LAT and BM at each of the three levels are represented as - E1, E2, and E3 respectively. For example values under column E1 in Tables 8 and 9 indicate the effect of each factor at level 1 (parameters are indicated in Table 1). From the two tables, the most significant factor R on the compressive strength at various testing periods is laterite content. It contributed the most effect among the three factors at each of the levels.

Table 4. Compressive strength of conventional concrete for 1:2:4 mix

	Days		
W/C	7	14	28
0.45	11.6	13.5	17.8
0.5	13	15	19.8
0.55	12.7	14.5	18.82

Table 5. Compressive strength of microbial laterized concrete cured in water

	Days	
TEST NO 7	**14**	**28**
1 14.07	15.53	19.85
2 16.20	17.19	19.11
3 12.15	13.78	18.52
4 18.96	24.44	27.85
5 17.43	20	24.15
6 12.44	14.07	18.67
7 15.56	18.67	22.37
8 13.63	14.81	19.85
9 10.96	13.62	18.52

Table 6. Compressive strength of microbial laterized concrete cured in nutrient broth medium

	Days	
TEST NO 7	**14**	**28**
1 14.07	15.53	19.85
2 16.20	17.19	19.11
3 12.15	13.78	18.52
4 18.96	24.44	27.85
5 17.43	20	24.15
6 12.44	14.07	18.67
7 15.56	18.67	22.37
8 13.63	14.81	19.85
9 10.96	13.62	18.52

Table 7. L9 (33 Series) orthogonal analysis on compressive strength of microbial laterized concrete cured in water

	Factors	E1*	E2*	E3*	R*
7-Day Compressive fc (MPa)	W/C	11.08	14.2	12.27	3.12
	LAT	14.59	12.39	10.57	4.02
	BM	11.83	12.89	12.84	1.06
14- Day Compressive fc (MPa)	W/C	13.32	16.94	14.65	3.62
	LAT	17.15	15.04	12.73	4.42
	BM	14.17	15.33	15.41	1.24
28- Day Compressive fc (MPa)	W/C	17.28	20.87	18.84	3.59
	LAT	21.08	19.43	16.47	4.61
	BM	17.93	19.65	19.41	1.72

Table 8. L9 (33 Series) orthogonal analysis on compressive strength of microbial laterized concrete cured in nutrient broth medium

	Factors	E1*	E2*	E3*	R*
7-Day Compressive fc(MPa)	W/C	14.1	16.4	13.48	2.92
	LAT	16.3	15.83	11.85	4.45
	BM	13.38	15.34	15.26	4.45
14- Day Compressive fc(MPa)	W/C	15.5	19.36	15.71	3.86
	LAT	19.56	17.33	13.68	5.88
	BM	14.57	18.42	17.49	3.75
28- Day Compressive fc(MPa)	W/C	18.67	23.55	20.25	4.88
	LAT	23.35	21.04	18.07	5.28
	BM	19.46	21.82	21.18	2.36

*E1, E2, E3, - Average effect of three factors at level 1, 2or 3
*R –Rank of significance among the factors.
BM – Bacteria Medium
LAT – Laterite Content W/C – Water Cement Ratio

Figures 4 to 6 show the average effect of each of the factors, from which it was observed that the optimum value for water/cement ratio was 0.50 and bacterial medium, 20%, while a negative trend was observed for laterite. However, at 20% replacement and applying the optimum conditions for water/cement ratio and bacterial medium, laterite can be used in structural concrete as compressive strengths as high as 24 N/mm2 are achievable.

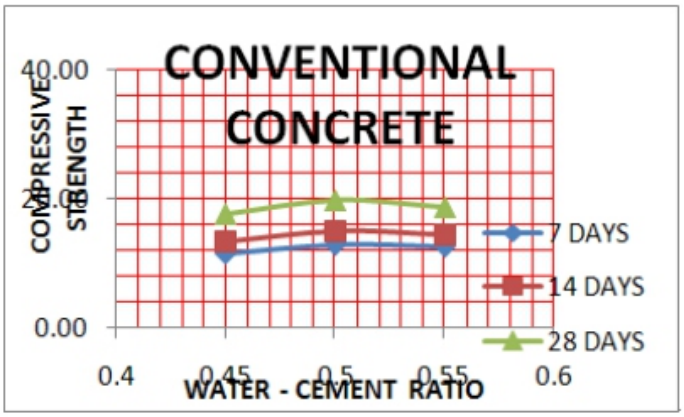

Figure 4. Compressive strength of conventional concrete for 1:2:4 mix

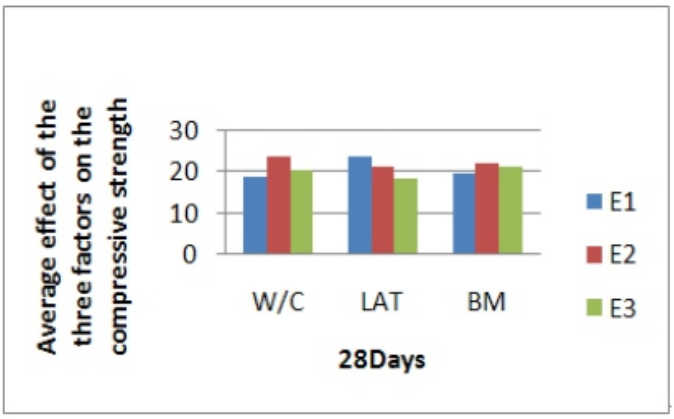

Figure 5. Orthogonal Analysis on Compressive Strength of Microbial Laterized Concrete Cured in nutrrient broth medium

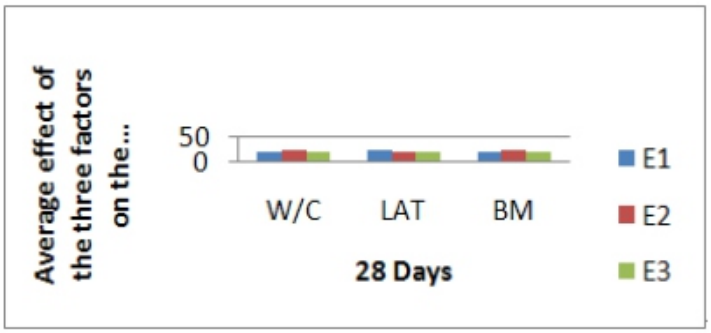

Figure 6. Orthogonal Analysis on Compressive Strength of Microbial Laterized Concrete Cured in water

The improvement in compressive strength by Bacillus sp. JC3 is probably due to the deposition of CaCO3 on the microorganism cell surfaces and within the pores of concrete, which plug the pores within the concrete [15-18] as reported by Achal et al [19].

It was also observed that concrete cubes cured in nutrient broth medium had the higher compressive strength which can be attributed to fact that microbial cells was able to get supplementary nutrient from the curing medium.

It is also possible that as the pH of concrete falls during carbonation, cells become active and as curing period was increased, it started growing slowly. Upon cell growth, calcite would precipitate on the cell surface as well as within the concrete matrix. Thus, the concrete becomes less porous/permeable This explains the behavior of the increased compressive strength at 28 days in concrete cubes prepared with microbial cells with cells either dying or forming protective endospores after some time.

6. CONCLUSION

Based on the present experimental investigation, the following conclusions are drawn:

- It has been generally observed that the addition of laterite to concrete causes a reduction in the compressive strength. However the addition of Bacillus Subtilis JC3 under optimized conditions enhanced the compressive strength of concrete, conventional and laterized alike.

- From the orthogonal analysis on compressive strength, the observed optimum value for water/cement ratio and bacterial medium were 0.5 and 20% respectively, while a negative trend was observed for laterite replacement.
- At 20% replacement for sand, laterite can be used in structural concrete as compressive strengths as high as 24 N/mm2 were attained in 28 days.

REFERENCES

[1] Shetty M. S. Concrete Technology, S. Chand and Company Ltd, Ram Nagar, New Deihi, 2004.

[2] Adepegba D. The Effect of Water Content on the Compressive Strength of Laterized Concrete, Journal of Testing and Evaluation. 3: 1-5, 1975.

[3] Adepegba D. Structural strength of short, Axially Loaded Columns of Reinforced Laterized Concrete. Journal of Testing and Evaluation. 5: 1-7, 1977.

[4] Lasisi F. and Osunade, J. A. Factors affecting the strength and creep properties of laterized concrete, Building and Environment. 20(2): 133-138, 1985.

[5] Salau M. A. Long-term deformations of laterized concrete short columns. Building and Environment. 38(3): 469-477, 2003.

[6] Jayawardena U. De S. and Dissanayake D.M.S., Use of quarry dust instead of river sand for future constructions in Sri Lanka. IAEG Paper No. 38, 2006.

[7] Jayawardena U. De S. and Dissanayake D.M.S. Identification of the most suitable rock types for manufacture of quarry dust in Sri Lanka, J. Natn. Sci.Foundation Sri Lanka. 36(3): 215-218, 2008.

[8] Osadebe N. N. and Nwakonobi T. U. Structural Characteristics of Laterized Concrete at Optimum Mix Proportion, Nigerian Journal of Technology, Nsukka, Nigeria. 26(1): 12-17, 2007.

[9] Ukpata, J. O., Maurice, E. E. and Akeke, G. A. Compressive Strength Of Concrete Using Lateritic Sand And Quarry Dust As Fine Aggregate, ARPN Journal of Engineering and Applied Sciences Vol. 7, No. 1, 2012.

[10] Salau M. A. Abundant Local Structural Engineering Materials without Affordable Structures - An inaugural lecture delivered at the University of Lagos, Nigeria. 23rd April, 2008.

[11] Khan, M. I. Isoresponses for strength, permeability and porosity of high performance Mortar, Building and Environment, 38, 1051-1056, 2003.

[12] British Standard Institute. Portland Cement (Ordinary and Rapid Hardening), BS 12, BSI, London, 1996

[13] Reddy S. P., SheshagiriRao M.V., Aparna P., Sasikala C.H. Performance of standard grade bacterial concrete, Asian Journal of Civil Engineering, 11(1), 43-45, 2010.

[14] Taguchi, G. Introduction to Quality Engineering: Designing Quality into Products and Processes, Asian Productivity Organization, Japan, 1998.

[15] Ramakrishnan, V., Bang, S. S., and Deo, K. S. A novel technique for repairing cracks in high performance concrete using bacteria, Proc. Int. conf. on high performance high strength concrete, Perth, Australia, 597-618, 1998.

[16] Ramachandran, S. K., Ramakrishnan, V., and Bang, S. S. Remediation of concrete using microorganisms, American Concrete Institute Materials J., 98, 3-9, 2001.

[17] Ghosh, P., Mandal, S., Chattopadhyay, B. D., Pal, S. Use of microorganism to improve the strength of cement mortar, Cement and Concrete Research, 35, 1980-1983, 2005.

[18] Achal, V., Mukherjee, A., Basu, P. C.,and Reddy, M.S. Lactose mother liquor as an alternative nutrient source for microbial concrete production by Sporosarcinapasteurii, Journal of Industrial Microbiology and Biotechnology, 36,433-438, 2009.

[19] Achal, V., Mukherjee, A., and Reddy, M.S. Microbial concrete: A way to enhance durability of building structures, Journal of the Department of Biotechnology and Civil Engineering, Thapar University, Patiala, Punjab, India, 2010.

ISSN: 2332-1091

Experimental Assessment of the Effect of PVC Attachments as Repair of RC Beams

David Naish*, Justin Nguyen, Oscar Jimenez, Brake Hoenisch
Department of Civil and Environmental Engineering, California State University, Fullerton, CA, 92832, USA
*Corresponding Author: dnaish@fullerton.edu

ABSTRACT

The purpose of this project is to test the effectiveness of using polyvinyl chloride (PVC) structural angles to increase the capacity of reinforced concrete (RC) beams. Two ½-scale beams with different reinforcement configurations were loaded to approximately twice the yield displacement, unloaded, and subsequently repaired and reloaded to failure. Results indicate that the PVC attachments increased the capacity of the beams by 10-15%. While the increase in strength was modest, it may be sufficient for cases in which only minor improvement is necessary and thus does not justify the high cost of other repair techniques.

Keywords Reinforced Concrete, Beam, Repair, Testing

1. INTRODUCTION

Reinforced concrete beams are commonly used in building applications due to their high strength and relatively low cost. During an earthquake, a building's primary lateral force-resisting system is expected to take the loading and sustain major inelastic deformations. However, the non-participating (gravity load-resisting) system must also sustain these inelastic deformations to maintain compatibility with the rest of the structure. Damage to these systems, especially in older buildings, is common, as is the need for their repair and potential retrofit [1].

Minor repair techniques may be used in cases where cracks form following extreme loading. These are not usually appropriate if there is major damage to the concrete or steel reinforcement. Epoxy injection of cracks is a method used for simple repair of small cracks [2]. It involves allowing a low-viscosity epoxy resin to fill in and re-bond cracks. The procedure is slow and labor-intensive, but does provide a reasonable option for returning the concrete to its pre-cracked state [3]. Minor repair techniques such as this do not typically provide improved behavior; rather they simply attempt to bring the material to its original state.

Major repair of structural members may be required when member. These techniques are somewhat easier to perform, but are intrusive as they take up usable space [4]. Strengthening techniques such as these are costly and used to dramatically improve the behavior of structural members that are deficient.

More recently-developed repair and strengthening techniques typically involve the use of high strength and stiffness carbon fiber reinforced polymer (CFRP) sheets that bond to the concrete using a low viscosity epoxy resin [5]. The procedure is fairly labor intensive and requires skilled workers to install. However, it is neither intrusive to the surrounding area nor invasive to the integrity of the structural member. Studies have shown that this repair technique is an excellent way to dramatically increase the elastic stiffness and strength of a concrete member, especially following minor damage [6, 7]. Due to the high strength and stiffness of the material, delamination failure in the epoxy is typically the most

common mode of failure for beams repaired with CFRP [8]. Additionally, changes to the stiffness of different elements in a structure can drastically affect the behavior of the system as a whole; even members that aren't considered part of the lateral force resisting system can be expected to cause redistribution of lateral forces if their increase in stiffness is sufficiently large [9].

The purpose of this study is to investigate the effectiveness of a repair system that is simpler to apply, but for cases where substantial improvements are not needed. This is often the case in older construction, whose design no longer meets the letter of the code. The only option is expensive retrofit or rehabilitation using one of the previously mentioned techniques, whereas only minor improvements are necessary to make the design strength sufficient.

2. MATERIALS AND METHODS

2.1. Test Specimen Geometries

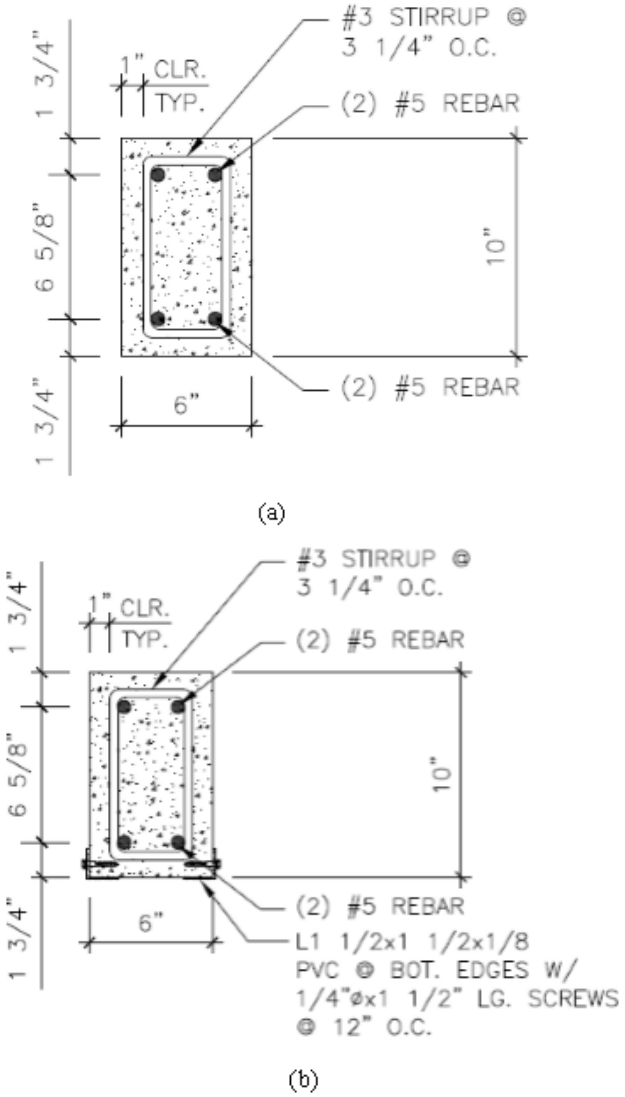

Figure 1. Cross section of (a) Beam 1and (b) Beam 1R and Beam 2.(1 in. = 25.4 mm)

In total, six different tests were performed on four specimens. The beam cross sections are shown in Figs. 1 and 2. All beams have the same cross section dimensions of 10" × 6"(254 mm × 152.4 mm) .

Beams 1 and 2 were reinforced with 2-#5 bars on the top and bottom. Beams 3 and 4 were reinforced with 2-#4 bars and 2-#3 bars in two layers at both the top and bottom. All four beams had the same reinforcement ratio. Beams 1 and 3 were loaded beyond the yield point and were then repaired by attaching 1.5" × 1.5" × 0.125"(38.1 mm × 38.1 mm × 3.18 mm) PVC angles with concrete screws at 12" on center. The repaired beams were then tested. The repaired specimens are indicated with an R after the name, Beam 1R and Beam 3R. Beams 2 and 4 were tested only after attaching the same 1.5" × 1.5" × 0.125"(38.1 mm × 38.1 mm × 3.18 mm) PVC angles to the bottom edges of the beams. All beams were 12' (3.65 m) long.

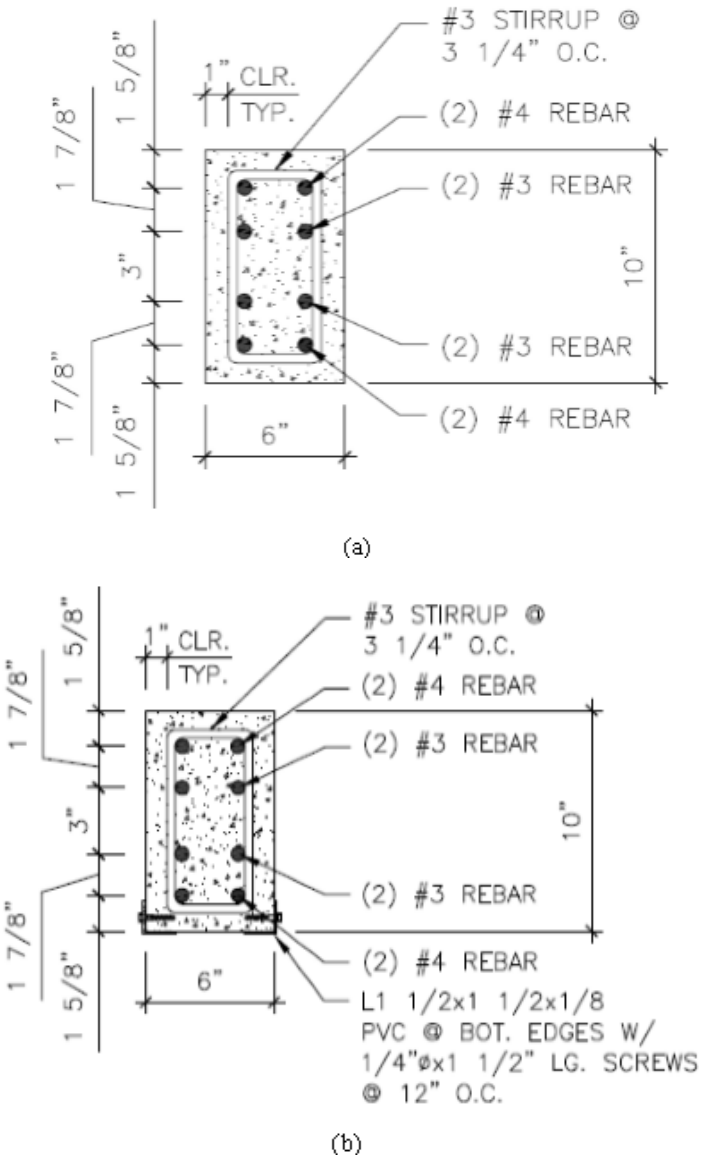

Figure 2. Cross section of (a) Beam 3 and (b) Beam 3R and Beam 4.(1 in. = 25.4 mm)

2.2. Material Properties

Concrete cylinders measuring 6" (152.4 mm) in diameter by 12" (304.8 mm) in height were cast along with the beams to measure the actual concrete compressive strength. Compression tests were performed on these cylinders and the average concrete strength was measured to be 5062 psi(34.9 MPa). Based on manufacturer specifications, the yield strength of the PVC was taken to be 12.8 ksi (88.3 MPa) and the modulus of elasticity was assumed to be 411 ksi(2833 MPa). For calculation purposes, the concrete was

assumed to follow a Hognestad stress-strain relationship, while the steel and PVC materials were assumed to follow an elastic perfectly plastic stress-strain model [10]. These material relations are summarized in Figure 3 below.

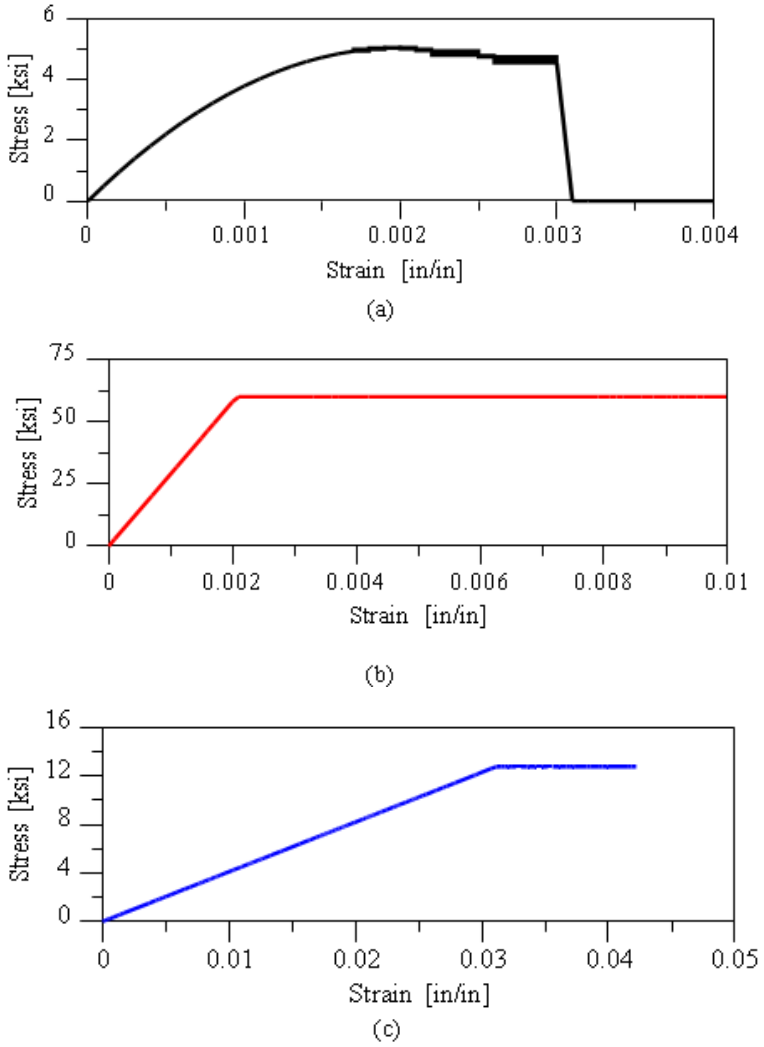

Figure 3. Stress-strain relationships for materials used in test specimens: (a) concrete, (b) steel, and (c) PVC. (1 ksi = 6.89 Mpa)

2.3. Test Setup and Instrumentation

All beams were tested using the same setup. End restraints for the beam were pin supports allowing free rotation. The clear span between supports was 11'-10" (3.61 m). Each beam was subjected to two equal point loads applied at +/- 1'-6" (+/-0.457 m) symmetrically about the centerline via a single actuator. The load was applied at a constant rate of 1000 lbs/min(4.45 kN/min) to ensure a quasi-static load rate.

The midspan displacement was measured by one +/- 5" (+/-127 mm) wire potentiometer attached directly to the bottom of the concrete beam. The load was measured by a load cell in the actuator. The test setup and external instrumentation scheme is shown in Fig. 4.

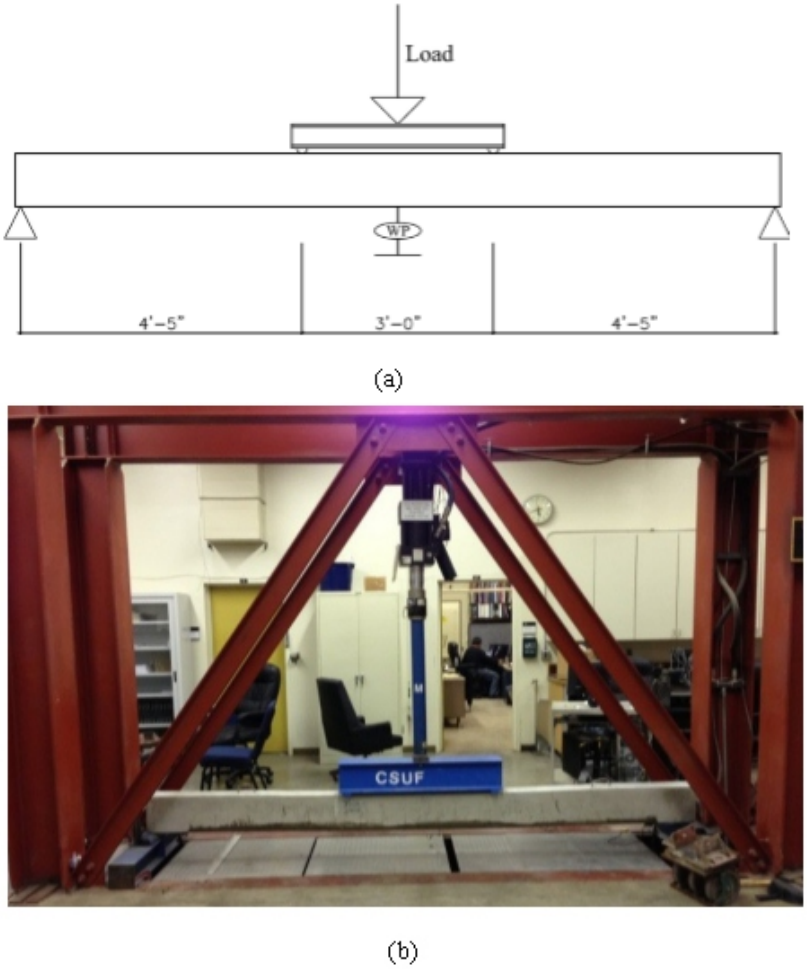

Figure 4. Experimental setup and instrumentation (a) schematic and (b) photo.(1 in. = 25.4 mm)

2.4. Repair Methodology

Beams 1 and 3 were tested beyond the yield point, unloaded, and repaired. Beams 2 and 4 were not repaired; rather they were prepared with the PVC angles prior to testing. The purpose of this was to directly gage the impact of the PVC itself, removing any effects of post-yield damage and strain hardening in the steel.

As discussed previously, many typical repair techniques involve the use of low viscosity epoxy resin in conjunction with fiber-reinforced polymer sheet or wrap. A similar approach was initially taken to repair the beams in this study with PVC angles. However, the low viscosity of the epoxy combined with the lack of flexibility in the PVC did not allow for adequate bonding with the concrete. Higher viscosity epoxy would have provided a better bond between the two materials. One problem with epoxy as a means for attachment in this specific application is the set/cure time. Typical set times range from five minutes to two hours with typical cure times ranging from one to seven days.The large set/cure time and the increased cost of the material may limit the use of high strength epoxies to situations where major repair is necessary. Additionally, special care must be provided to ensure that the epoxy is uniformly applied along the entire length of the repair region. Any gaps in the glue could present potential failure planes and lead to premature delamination.

For the purposes of this study, the PVC angles were attached with concrete screws. This was accomplished by first clamping the angles to the concrete at the bottom corners.Holes were drilled at 12” (304.8 mm) on center on both the sides and bottom of the beam using a masonry drill. Finally, 1/4” (6.35 mm) diameter concrete anchors were screwed into the concrete using an electric drill. Specifically, Tapcon0.25”× 1.75” (6.35 mm × 44.5 mm) blue hex-head concrete anchors were used. Note that the screws had a sealed finish to provide durability and resistance to corrosion, but were not additionally sealed or anchored in epoxy. The installation process was simple and cost-effective as it could be completed by one worker, or by two workers in an assembly line fashion. Due to the scale of the test specimens, it was necessary to embed the screws in the cover concrete. This is undesirable as the cover concrete does not provide substantial embedment, especially in the case of cyclic loading. That is not a major concern in the case of a gravity system however, as the screws are anchored in the tension regions of the beam. However, the presence of the screws does introduce a potential crack initiation point. An elevation view is shown in Figure 5 below.

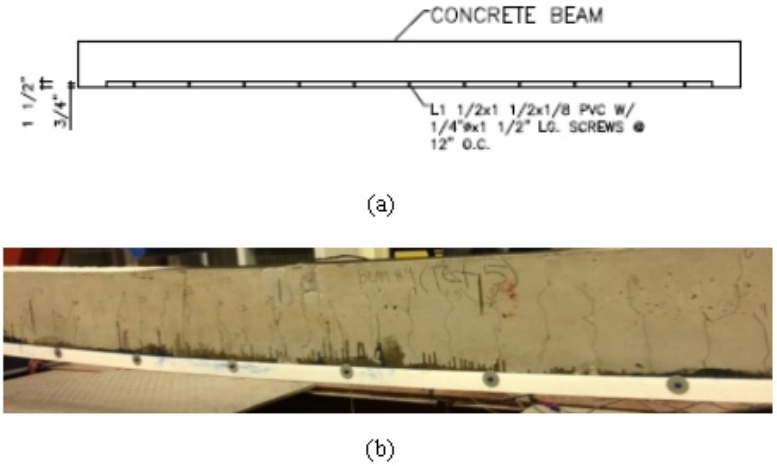

Figure 5. Repair methodology (a) schematic and (b) photo. (1 in. = 25.4 mm)

3. RESULTS AND DISCUSSION

Results are presented in three forms: 1) expected strength and stiffness based on moment - curvature, 2) experimentally determined strength and stiffness based on load - deformation behavior, and 3) observation of damage during testing.

A moment – curvature analysis was performed on the four beam cross sections tested using the material properties described in section 2.2. The predicted moment vs. curvature behavior of the specimens both with and without PVC are shown in Figures 6 and 7 below. These figures show the expected effect of the PVC on the behavior of the reinforced concrete beam. In both cases, because the PVC was of very low stiffness compared to the reinforced concrete, the elastic behavior of the beams was unaffected by the presence of the additional material. This is important to note as substantially changing the stiffness of the structure can change the overall behavior of a structure [9]. Specifically, changes in stiffness to certain members can alter load distribution throughout the structure. This is an important fact for gravity systems as they are typically designed to be much less stiff elastically than the lateral force resisting systems. If the gravity members are substantially stiffened, they may take more load than that for which they were originally designed.

While the relatively low stiffness of the PVC resulted in minimal impact on the elastic behavior of the beams, once those beams started to yield and deform more substantially, the PVC was able to develop more of its strength. This allowed for a nominal increase of 10 – 15% in strength in the post-yield range. While the expected increase was not substantial, it may be sufficient for cases where only small repair or improvement is necessary. Specifically, oftentimes a code change will result in a deficiency within a structural member. Even if the deficiency is small, retrofit or replacement of the beam may be required. In cases where the strength is deficient by only a small amount (< 20%), costly retrofit options such as those discussed in section 1 could be avoided by implementing a cheaper alternative.

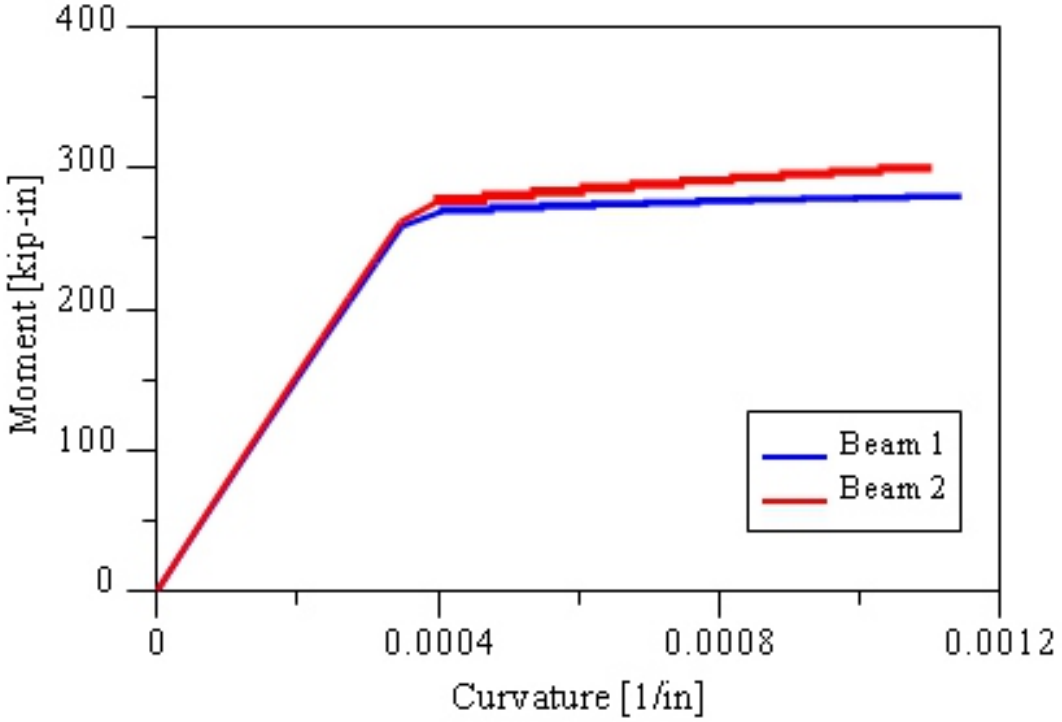

Figure 6. Moment-curvature relationship for Beams 1 and 2.(1 in. = 25.4 mm, 1 kip. = 4.45 kN)

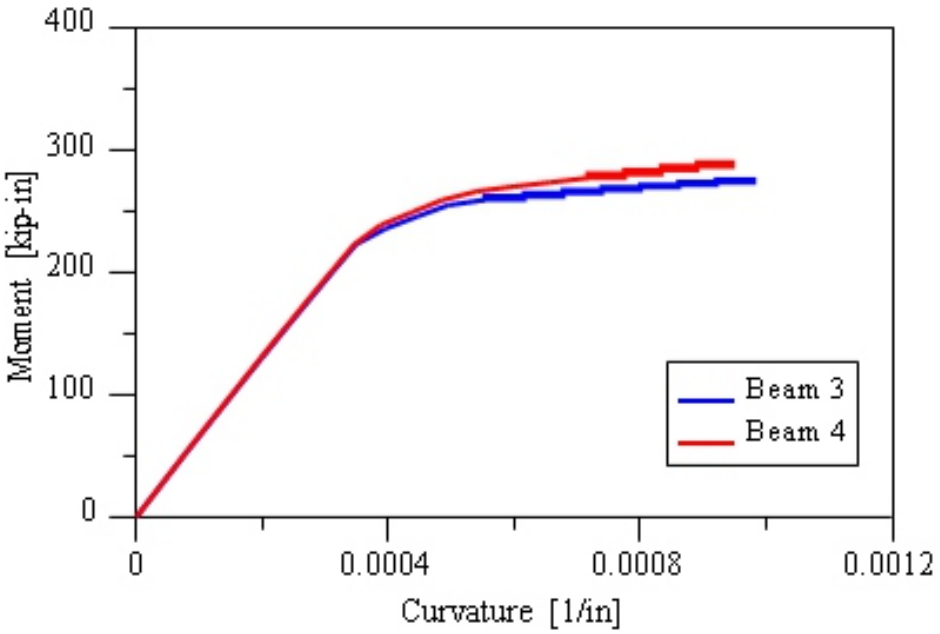

Figure 7. Moment-curvature relationship for Beams 3 and 4.(1 in. = 25.4 mm, 1 kip. = 4.45 kN)

Experimental results are presented as plots of the total load applied (distributed equally to two point loads) and the displacement at midspan of the beam. Figures 8 and 9 experimentally show the impact of adding the PVC to the beams both as additional reinforcement and as repair following preliminary loading and damage. As expected, the PVC did not drastically impact the elastic behavior of the beams. In fact, all but one of the six tests had almost identical stiffness in the elastic range. Only one specimen, Beam 1R, deviated from this trend. The impact is fairly minor however due to the fact that the specimens still yielded at the same displacement. While the PVC did not have a major impact on the elastic behavior of the beam, its effect on the post-elastic behavior was noticeable. In each case the PVC provided a 10-15% increase in strength, a fact which is consistent with the expected results. Specifically, Beam 2 yielded at the same point (load and displacement) as Beam 1 but increased in strength compared to Beam 1 at a linear rate post-yield. Conversely, Beam 4 yielded at a higher load and displacement than did Beam 3, but maintained a consistent increase in strength in the post-yield region.

The repaired beams showed an even further increase in strength over those with pre-installed PVC. Specifically, the strength of Beam 1R was approximately 30% higher than that of Beam 1; and Beam 3R was approximately 35% higher in strength than Beam 3. This is likely a result of the increased steel stress due to strain hardening in the steel following initial loading. This is expected, as strain hardening in the steel reinforcement can be expected to contribute approximately 15-20% to the strength of a beam loaded beyond the yield point, unloaded, and subsequently reloaded. This increase in addition to the 10-15% from the PVC material can be said to cause the overall 30%-35% increase in strength from the original unrepaired beam .

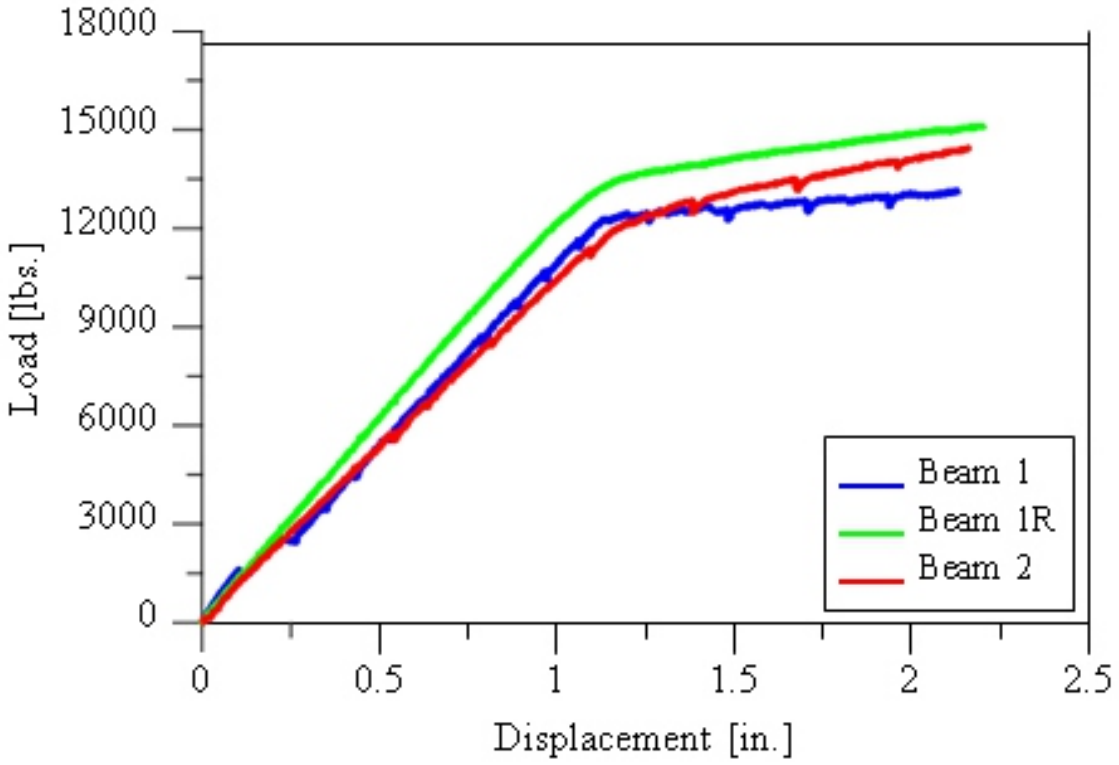

Figure 8. Experimental load-displacement results for Beam 1, Beam 1R, and Beam 2. (1 in. = 25.4 mm, 1 lb. = 4.45 N)

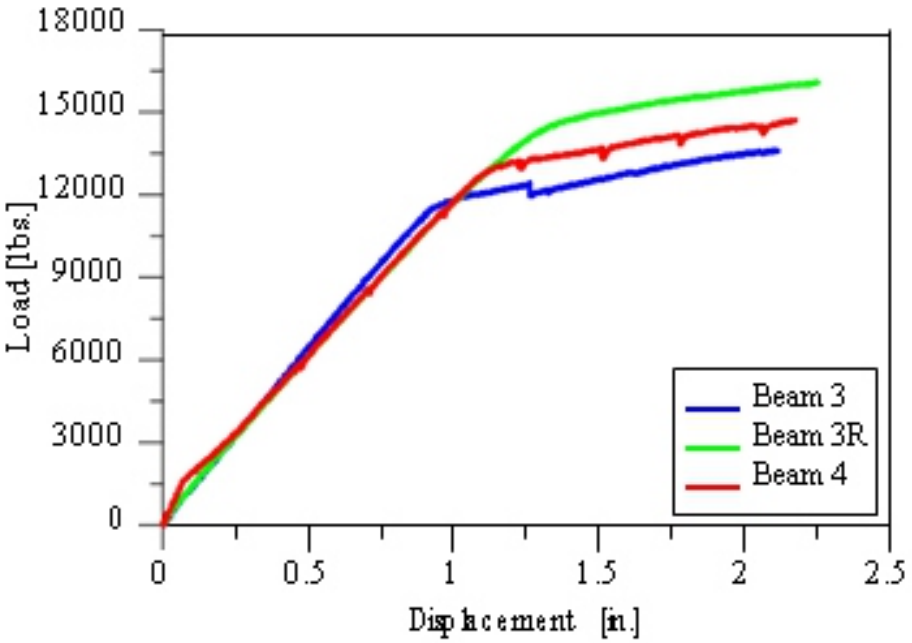

Figure 9. Experimental load-displacement results for Beam 3, Beam 3R, and Beam 4. (1 in. = 25.4 mm, 1 lb. = 4.45 N)

Damage and cracking patterns were very similar for all test specimens. Some forms of repair aim to reduce the physical damage to the beam (cracking, spalling, etc.). Because the PVC has a much lower stiffness than the reinforced concrete, mitigating cracking was not a major objective. Due to the screws being anchored in the cover concrete, additional damage was observed at several of the screw locations at high displacement levels. Specifically additional cracks initiated at the screw locations. This cracking did not affect the behavior of the test specimens, nor did it induce spalling of the cover concrete, even at very high displacement levels. But it is indicative of one problem with this repair technique in that it does in fact introduce some damage to the beam. This is important to note, as this additional damage is a detriment to the overall improvement in behavior due to the additional material. Therefore, one key recommendation is that the screws be anchored in the confined portion of the concrete in full-scale applications to help mitigate the damage of the anchors.

4. CONCLUSIONS

A total of six tests were conducted on four specimens to assess the impact of using PVC angles as a simple and modest repair technique for reinforced concrete beams. The main conclusions of the study are summarized below. Please note that these conclusions are based on the small scale tests performed. Therefore caution should be exercised when extrapolating these results to full scale beams.

- The PVC angles provided a 10-15% increase in strength in the tested specimens. That increase is consistent with the expected increase in flexural strength due to the addition of PVC material. While the increase in strength is not substantial, it is sufficient for cases where only minor repair is needed. Therefore, it can be considered a cost-effective alternative to more expensive repair techniques that aim to dramatically change the behavior.
- Due to the relatively low stiffness of the PVC material, the elastic behavior of the beams is unaffected by the application of repair. This fact means that the elastic behavior of the structure as a whole is not going to change. This is an important fact in repair/retrofit considerations as changes to the elastic properties can have effects on the overall system behavior.

- Because the PVC angles are attached via concrete screws and not epoxy resin, delamination failure is not possible. Rather, the only failure that might be expected in the PVC is a bearing failure at the connection points. However, due to the flexibility of the material, this failure mode is unlikely.
- When attaching the PVC angles, it is important to embed the anchor screws sufficiently into the beam core. This will ensure that shear is adequately transferred between the concrete and PVC even if the cover concrete begins to spall at high displacement levels.

ACKNOWLEDGEMENTS

The authors acknowledge the Department of Civil Engineering at California State University Fullerton for support of this research.

REFERENCES

[1] A. Balsamo, A. Colombo, G. Manfredi, P. Negro, A. Prota. Seismic behavior of a full-scale RC frame repaired using CFRP laminates.Engineering Structures, Volume 27, Issue 5, (2005): 769–780.

[2] M. Murra. Epoxy injection welds cracks back together. Concrete Construction 3 (1987).

[3] D. Fowler. Polymers in concrete: A vision for the 21st century. Cement and Concrete Composites, Volume 21, Issues 5-6, (2006): 449-452.

[4] G. Chynoweth, et al. Concrete repair guide. ACI committee, concrete repair manual 546 (1996): 287-327.

[5] N. Grace. Concrete repair with CFRP. Concrete international 26.5 (2004): 45-52.

[6] S. Pendhari, T. Kant, Y. Desai. Application of polymer composites in civil construction: A general review. Composite Structures 84 (2008): 114-124.

[7] P. R. Chakrabarti, D. Millar, and S. Bandyopadhyay. Application of composites in infrastructure. Proceedings of the Third International Conference on Composites in Infrastructure(2002).

[8] C. Leung. Delamination failure in concrete beams retrofitted with a bonded plate. Journal of Materials in Civil Engineering 13 (2001): 106-113.

[9] D. Naish. Testing and modeling of reinforced concrete coupling beams. Dissertation. University of California Los Angeles (2010): 251 pp.

[10] E. Hognestad, N. W. Hanson, and D. McHenry. Concrete stress distribution in ultimate strength design.ACI Journal Proceedings. Vol. 52. No. 12. (1955)

ISSN: 2332-1091

Examining the City Brand Theory and Presenting Some Solutions for Implementing of It in Iran

Mohammad Reza Sadeghi Moghaddam[1,*], Tannaz Assadollahzadeh[1], Mehdi Mirmoini[1], Salameh Azimi[2]

[1]Department of urban planning, Qazvin Branch, Islamic Azad University, Qazvin, Iran
[2]Department of Industrial Engineering, Qazvin Branch, Islamic Azad University, Qazvin, Iran
*Corresponding Author: m.sadeghi62@gmail.com

ABSTRACT

Iran is a country with great tourism potentials. Having ecological and cultural diversity, ancient history, beautiful historical and architectural urban spaces and buildings, natural resources, tourism attractions and hospitable residents could have benefited Iran in the globalization process if it had a globally positive image and sense of place. Branding cities is a tool that assists to make a region, country or city widely recognized and is studied in this paper as a means to better Iran's global reputation and image. In the end it was concluded that the key to branding Iran is in the hands of its own residents and governors.

Keywords City Brand, Iran, Branding cities, Tourism, Berlin, New York, Globalization

1. INTRODUCTION

In today's globalized world, it is essential for the cities to compete with each other to attract tourists, investments, businesses, new inhabitants and other factors which are necessary for being successful in the globalization process. Many attempts have been made to redefine urban spaces by using such terms as world cities, cultural cities, compact cities, creative cities, or endless cities [1]. In recent years cities are in search for new ways to promote themselves. Due to fast changes in technology and the shift from local to a globalized environment, cities are forced to compete with each other in order to be an attractive tourist destination, workplace, cultural rich place and much more [2].

As C.-J. Lee proposed that city branding is a new theory for showing a city as a special brand for developing mature methods of commencing traditional markets, services and applying them in region, city or country [3].

Good branding may assist in making cities desirable just as bad branding may assist in making cities undesirable. A city must have certain qualities in order to brand itself successfully, but a myriad of factors are involved. Cooperative efforts between residents and municipal government are one of the key factors in determining the branding potential of a city [4].

Successful city branding depends greatly on the identification of distinctive and defining characteristics possessed by the city in question. Characteristics of a city are both functional and non-functional qualities, which include, among others, city appearance, history, cultural attractions, demographics, economics and governance, people's experience of the city and people's perception of the city. Consensus on the city's identity and core values, between the city authorities and the general public, is one of the key factors in achieving the success of city branding [5].

This paper focuses on the definition of a city brand and the effects of branding cities, then two cities, New York and Berlin which have a positive brand images are described.

At the end Iranian cities are compared with New York and Berlin and some applicable recommendations for improving their brand images and taking part in the competition of the globalized cities are presented.

2. CITY BRANDING?

Present Globalization has made it easier for newly developing cities to compete with older more established cities, simply because people can live and work almost anywhere now [4].

The fact demonstrates that, the competition between the cities is harsh, because of economical and political effects of globalization. The cities are competing to attract investments, influence, businesses, residents.

One of the challenges of urban management in its efforts to grow the performance is linked around the construction of the urban brand as a solution in the process of the cities' development [6].

In the last years, the conception that a country, a region or a city can transform in a brand won more and more partisans and started to obtain more attention both from the practitioners, and the theoreticians [6].The city brand is gradually becoming the most precious and valuable tangible assets of the city. And its values lies not only in the fact that it can help city to set up a good image and high prestige for the city, but also that it can unceasingly create new values[4].

This phenomenon provides, on one hand, the basis for developing policy to pursue economic development and, at the same time, it serves as a conduit for city residents to identify with their city [8]. Actually a brand is the foundation that helps to make a place desirable as a business location, visitor destination or a place to call home [9]. A successful brand is one that generally creates a powerful and unique image for the city and forgetting the strong bond between city branding and city image is unbelievable. Because of understanding the city brand functions, focusing on the effects of a good city image is necessary.

An image is the result of various; different and often conflicting messages sent by the city and are formed in the mind of each individual receiver of these messages separately [8]. The image of a city is actually the one characteristic of the city that has been highlighted throughout the years and is mostly conceived by experience. The people of the city and even the outsiders are aware of this quality and associate it with the name of the city. It plays an important role in the relief of the labor force and the students with potential to choose that place [6]. In general, people make sense of places or construct places in their minds through three processes. These are first, through planned interventions such as planning, urban design and so on; second, through the way in which they or others use specific places; and third, through various forms of place representations such as films, novels, paintings, news reports and so on. It is generally acknowledged that people encounter places through perceptions and images [10]. So it can be concluded that the first step of the branding of a city is to find this important quality and make it more tangible and distinct.

Paris is romance, Milan is Style, New York is energy, Washington is power, Tokyo is modernity and Barcelona is culture. These are the brand of the cities that make a positive image and work as a tool that can be used by cities to define themselves and attract positive attention in the midst of an international glut [9].

Currently, there is general preference in the marketing literature that the brand is more than a name given to a product; it embodies a whole set of physical and socio-psychological attributes and beliefs [8] and place branding is a strategic process for developing a long-term vision for a place that is relevant and compelling to key audiences. Ultimately, it influences and shapes positive perceptions of a place [9].

3. THE IMPORTANCE OF BRANDING CITIES

There are reasons why people choose particular cities in which to live. Certain cities are making comebacks even when the industries they were built on have become obsolete. Brands evolve, and cities that survive have managed to evolve [4].Therefore market fundamentalists and some international organizations, such as the International Monetary Fund (IMF), the World Bank, the World Tourism Organization, and the World Economic Forum, enthusiastically urge cities to seek competitive advantages as a means of survival and prosperity [11] since city branding is understood as the means both for achieving competitive advantage in order to increase inward investment and tourism, and also for achieving community development, reinforcing local identity and identification of the citizens with their city and activating all social forces to avoid social exclusion and unrest [8].

There are many reasons why it is critical for a place to have a brand strategy, but the most common is to stimulate economic growth. That's because a strong brand can:

1) Shift the perception of a place that may be suffering from a poor image among external and internal constituents.
2) Create a common vision for the future of the community and its potential.
3) Provide a consistent representation of the place.
4) Enhance its local, regional and/or global awareness and position.
5) Shed unfavorable stereotypes associated with a place and make it more appealing [9].

There are even more important reasons to study the need and potential of a place or city branding. A positive powerful image has the capacity to offer a city a competitive solid and distinctive advantage. Moreover, it can influence the decision in the process of choice of the places for direct foreign investments and affects the attitudes towards the services and products of that place, of its ability to attract tourists and entrepreneurial activities [6].

4. CREATING A CITY BRAND

The image of a city, in the sense of the general meaning and idea of a place, is formed not only by visual images, but also by many other elements

The building of a city brand is a huge project, involving economic, environmental, social and many other factors [12]. And in order for a city to be a good brand, it must possess defining and distinctive characteristics that can be readily identified. These are functional as well as nonfunctional qualities. These include city appearance, people's experience of the city, people's belief in the city, what the city stands for, and what kind of people inhabit the city [4].

The construction of positive and charming images is a fundamental tool for attracting global flows of tourism and investments to promote local development (Gold and Ward, 1994)[13], Florida (2002)[14], who has affirmed that the creative class is attracted by cool cities (more on this later), fits implicitly into this theoretical frame.

Marketing managers everywhere seem to have different views on how cities should be branded. City planners think they understand their "city brand", but more often it is an enigma. Planners discover they cannot really define their city brand, but few are willing to admit it; and if you don't define your own brand no one else is likely to either [4]. But there is the general agreement that a powerful city brand must be created holistic, because the entire city represents a brand. In the creation process of the brand, some aspects, such as images, characteristics and experiences are usually selected, while others are eliminated [6].

In order to create a good brand for our city, we must know that a good city must have the following characteristics:

1. Offer attractive employment.
2. Not be unduly expensive in relation to wages.
3. Have reasonable public transportation
4. Have good schools and recreational/cultural attractions.
5. Have a reasonable climate.

And the way that brands work for a city is how these qualities are projected: by word-of-mouth, public relations, and in some cases, advertising [4].

As we discussed in the above sentences the first step of branding cities is to find its image and once the urban planners understand the current image of the respective city, they can deliberate regarding the type of image that can be built accordingly. One of the challenges that result from this situation is the creation of an image that determines efficient results for all the target-groups. The eligibility conditions of an urban image to the title of universally available efficiency are:

a) Validity: If the place promotes an image being too far from the reality, the chances of success are minimum.

b) Credibility: The exaggerated efforts of promotion become dangerous if they are practiced on long term.

c) Simplicity: Because most of the cities do not develop promoting strategies, they tend to disseminate any information a little positive, without making a profound analysis of it; so, the priority process is usually inexistent, generating an exhaustive promotion and implicit, confusion in the target-groups.

d) Attractiveness: The image must offer reasons to generate the wish of the individuals to visit, live, invest or work in the respective place. For this, it is based on the promotion of different attributes like the economic stability, quality of life, opening towards exterior, infrastructure etc.

e) Distinctiveness: The image "works" most efficient when it approaches differently other common themes [6].

5. INTERNATIONAL EXPERIENCES

In this paper the branding process of New York and Paris is studied in order to use the planners' experiences in these cities to set a benchmark for the Iranian cities.

5.1. New York

New York is the most populous city in the United States which is in the center of New York Metropolitan area. Nowadays it has a significant impact upon commerce, finance, media, art, fashion, technology, education, and entertainment and also as the home of the United Nations Headquarters, it is an important center for international diplomacy and has been described as the cultural capital of the world. The story of the branding of the New York City is the story of the way a city in crisis was sold to the world. Although New York has had many attractions both for the tourists and the citizens including the Central Park, the Empire State building, Greenwich Village, the MET, the Museum of Modern Art, the Statue of Liberty, Times Square, the United Nations Building, the New York Public Library, the Guggenheim and others throughout the years; but as Pfefferkorn [4] includes it has not always been successful attracting and maintaining a population base. This was especially true in the early 70's through the mid-80 when riding the subway became a means of survival rather than a means of transportation. Between 1970 and 1980, the city lost nearly 825,000 residents, by far the largest loss ever sustained over a 10 year period by a major U.S. city. This was primarily due to crime, high housing costs, and density of living [4].

As the New York State was in a deep economic slump and New York City was crime-ridden and bankrupt at the year of 1977 they decided to spend an amount of money to see what they could do to make the terrified tourists reconsider. There were two major branding efforts in the New York City, the first on is the creation of a campaign with the slogan of "I Love New York" that was created along with the campaign which is still one of the most recognized and successful campaigns in the history of great emotional branding. The goal of this campaign was to share all the hidden treasures that New York State hold. They actually reached to their goal by the means of advertisement like creating a logo for their slogan, selling T-shirts which the slogan was written on, media and other means of advertisement. I LOVE NEW YORK is the official State of New York slogan, and is still used to promote New York today.

The second effort was to decrease the amount of crime, because crime was the most important reason the population was moving out of the city. They came to this agreement by the "Broken windows" theory that Pfefferkorn [4] describes as the following: if a window is broken and left unrepaired, people walking by will conclude that no one cares and no one is in charge. Soon, more windows will be broken, and the sense of anarchy will spread from the building to the street, sending the signal that 'anything goes'. This is the epidemic theory of crime. It says that crime is contagious, just as a fashion trend is contagious [4].Therefore they attacked the heart of the New York City's crime which was the subways and as a symbolic gesture wiped out any sign of the graffiti off the faces of the trains to send out a message to the vandals that disorder would not be tolerated. It was the efforts in the branding of the New York City that made it what it is today, a prosperous city with a powerful economy and a tourist destination.

5.2. Berlin

According to Berlin's origin in the 12th century, it is one of Europe's younger cities, which was emerged by the union of Berlin and Cölln.

For the first time on 28 October 1237 Cölln was mentioned in documents and so was Berlin in 1244. Unfortunately, most documents about those days were damaged by town center fire in 1830. The cities formed a union in 1307, and at last Berlin and Cölln joined and were named as Berlin in 1709. Before that Berlin- Cölln was in trouble with its population, after Bubonic killed some 4000 people and during

thirty years war the population reduced to 6000 from 10000. In 1640 during Frederick's government, Berlin reached 20000 inhabitants for the first time and then in 1701 king Frederick made Berlin the capital of Prussia. In 1709 Berlin had 60000 inhabitants. Berlin's population did not change until 1871, after that Adolf Hitler came and had so many plans to transform Berlin, because he thought that Berlin was one of the ugliest cities in the world. Berlin was to be renamed as "Germania" and hold 170000 people. But the construction never started because of the war.

By the end of the Second World War, up to 70% of Berlin had been destroyed [4]. In 1994 Berlin was divided into west-Berlin and east-Berlin and when the Berlin wall was constructed it physically separated them up to 1989 that it was destroyed. By the time of German reunification on 3 October 1990, the wall had been almost completely demolished, with only small sections remaining [4], and once again Berlin became the capital of Germany.

Berlin was once a city with beautiful architecture and culture, an unusual mix of architecture that after all the difficult history in the 20th century, showed all the darkness of its past. And nowadays has many attractive places to visit from earlier centuries, like opera houses, theaters, museums, galleries and film festivals.

Although Berlin was a beautiful and historical city, it did not have the proper brand image that other European cities like London, Rome and Paris had. So it was in the middle of a harsh competition with the other European cities to play a role in the globalization process.

It could be said that the biggest branding problem that Berlin must have had faced was the effects of Nazi crimes during Second World War and the Berlin wall. Berlin's branding process was the question of how to use its both positive and negative qualities to save it from its dark past towards a promising future. One of the biggest branding efforts in Berlin was the creation of a campaign with the slogan "be Berlin". Be Berlin was called to life in the spring of 2008. In the first year, the campaign to market Berlin primarily addressed a regional audience with its signature features, the red frame and the three-part phrases, "be…, be…, be Berlin". Since 2009, the campaign has used the slogan "the place to be" Internationally and promotes Berlin in particular via the "Berlin Days" as an attractive location for art and culture, for business and science, and also to live and work. The "be Berlin" brand has been successfully established. Individual, successful projects will be further developed as part of the brand campaign for distinguishing the capital and the location [15].

6. CASE STUDY OF IRAN

As it was discussed in this paper, city branding is essential to attract tourists and foreign investors. In the last 3 decades the importance of tourism has gained the attention of many experts in Iran and the government and the private sectors have contributed a lot to the process of tourism development. Although Iran has diverse climate and environment and also prosperous historical and cultural background, hasn't taken a part in the globalization process. Not only tourism is a problem for Islamic culture and beliefs but also can play an important role for economic development. Such as, some Islamic countries, Turkey, Malaysia, Egypt, Tunisia and the UAE, especially the ones that are based on oil trade. But in spite of all the efforts made to use this as an advantage no progress has been made, and even most of Iranians spend their time and money in the foreign countries. Some important reasons of false Iran's brand could be as follows:

[1] The false impression that foreign people have about Iran.
[2] The negative publicity that has been made through foreign media about Iran.
[3] Since a bad advertisement against Iran, few foreigners know Iran truly.
[4] The middle-east's unstable situation has kept away tourists from traveling to the most of the region.
[5] Bad Iran intra-urban public transportations.
[6] The lack of quality in the recreational facilities.

7. RESULTS

After studying the definition of city brand, the way it is created and the branding efforts of New York and Berlin the reasons to their successful branding efforts became clear. The first lesson that is learned by studying the branding stories of New York and Berlin is that planners should focus on cities' strengths and improving their weaknesses. New York wouldn't be a successful branded city, if its crime problem hadn't been solved or neither would Berlin, if the effects of the Second World War hadn't been wiped out. These cities are distinctive, have values that are not available anywhere else, and there is no confusion about as what the city stands for. These values and qualities are spread by the word-of-mouth, advertising, graphic design, etc. However it shouldn't be neglected that cities must also offer what they claim to; otherwise, they wouldn't achieve their goal.

Identifying Iran's city branding problems, and having studied the branding stories of New York and Berlin some good and applicable suggestions are presented as follows:

i. Increasing in the government's awareness of the importance of branding cities.
ii. Establishing campaigns to promote Iran's brand.
iii. Choosing the perfect slogan for the brand of Iran and advertising it by the means of graphic design, logos and internet advertisements.
iv. Introducing Iranian prosperous history and culture and also its climate and environmental diversity.
v. Focusing on the Iranian hospitality in the advertisement programs.
vi. Designing new tourism websites and optimizing the existing.
vii. Optimizing the intra-urban public transportations and developing the traveling agencies to facilitate travels between tourist destinations.
viii. Making the historical and architectural places more distinct and popular like the Milad tower in Tehran.
ix. Developing the infrastructures to hold sport mega events to demonstrate Iran's brand.

8. CONCLUSION AND DISCUSSION

Brands are the names given to products or places showing the[i1r1u] nLiq.u Sehqeunagl.it Rieesthainnk dincghatrhaectiemripsatcictss,ocfrefoarteeidgnasinavestors onconsequence of growing competiveness and globalization. This research discusses the importance of considering this phenomenon in the comprehensive plans of the cities of countries like Iran, which have a false brand image and thus, couldn't have attracted tourism, businesses and investments to develop their economy, then identifies that increasing in the Iranian people and city planners' awareness of the importance of city brand and improving Iran's image and publicity are the first steps towards a more promising future.

REFERENCES

[1] T. Abe and S. Nishigaki, Nihon bunkashi handobukku (Handbook of Japanese Cultural History). Tokyodo Publishing, 2002.

[2] M. Riza, N. Doratli & M. Fasli, Procedia - Social and Behavioral Sciences 35, 293 – 300, 2012.

[3] C.-J. Lee. Effects of sport mega-events on city brand awareness and image: using the 2009 world games in Kaohsiung as an example, Quality & Quantity, Springer, 2013.

[4] J.W. Pfefferkorn. THE BRANDING OF CITIES, Exploring City Branding and the Importance of Brand Image, Master Thesis, Syracuse University, August 2005.

[5] L. Zhang, S. Xiaobin Zhao, City branding and the Olympic effect: A case study of Beijing Cities 26, 245–254, 2009.

[6] R.I. Popescu, R.A. Corboş. Strategic Options in the Construction of the Bucharest Brand through the Application Analysis of the Measuring Instruments for the Urban Brands, Annals of the University of Petroşani, Economics, 10(1), 267-278, 2010.

[7] Wu Qingjun. The scheme of Rizhao city brand, Operation and Management College, International Business Research, 1, (3), 67-79, 2008.

[8] M. Kavaratzis. From city marketing to city branding: Towards a theoretical framework for developing city brands, Place Branding,, 1: 1, 58-73, 2004.

[9] Prophet Consultancy. CEOs for Cities. Branding your city, a guidebook for city leaders, 2006.

[10] M.Kavaratzis, G.J.Ashworth, City branding: an effective assertion of identity or a transitory marketing trick, Tijdschrift voor Economische en Sociale Geografie, 96: 5, 506-514, 2005.

[11] L.Sehqeunag. Rethinking the impacts, of foreign investors on urban development: the city of Macao, The Annals of Regional Science, 49, (1), 73-86, 2012.

[12] Z. Jing-Yuan. Beijing International IT R&D Hub IT R&D Hub. The China Information Technology Handbook, Springer, 1-2, 2009.

[13] J.R. Gold, and S.V. Ward, Introduction. In Place Promotion. The Use of Publicity and Marketing to Sell Towns and Regions, S V Ward and J R Gold (eds.), 1–17, 1994.

[14] R. Florida, The Rise of the Creative Class. And How It's Transforming Work, Leisure, Community, and Everyday Life. Basic Books, New York, 2002.

[15] Berlin's Branding Campaign, Online Available from http://www.berlin-partner.de/en/marketing/image-campaign/, [Accessed 12th June 2013]

ISSN: 2332-1091

Sustainable High-Rise Design Trends – Dubai's Strategy

Xiao-Hua Jin[1,*], Guomin Zhang[2], Jian Zuo[3], Stephen Lindsay[4]

[1]Program of Construction Management, School of Computing, Engineering and Mathematics, The University of Western Sydney, Penrith Campus, Kingswood, New South Wales 2747 Australia

[2]School of Civil, Environmental and Chemical Engineering, College of Science, Engineering and Health, RMIT, GPO Box 2476, Melbourne, Victoria 3001 Australia

[3]School of Natural and Built Environments, University of South Australia, Adelaide, South Australia 5000 Australia

[4]Coffey Projects, Level 7, 1 Southbank Boulevard, Southbank, Victoria 3006 Australia

*Corresponding Author: xiaohua.jin@uws.edu.au

ABSTRACT

Until recently, the construction industry in Dubai was the creator of unsustainable world breaking high rise towers. This approach led to Dubai becoming labeled as the largest polluter in UAE and seen by the construction industry worldwide as an example of an unsustainable city. The current global crisis, however, has provided Dubai with the opportunity to firstly understand the benefits of sustainable practice and then implement this concept strategically within the construction industry. This study aims to identify the prototype for sustainable high rise design trends for the future by examining whether the future high rise towers align with the Dubai Government's strategy based on a number of case studies. It is within this context that this research generates a discussion regarding the Dubai Government Strategic Plan (2015) in conjunction with the recently revised green building rating system BREEAM Gulf and establishes that sustainable high rise buildings are being promoted throughout these strategies. Furthermore, this research presents case studies which discuss the future high rise functional use trend, the Burj Dubai / Nakheel Tower and the Dynamic Tower, leading to a determination being made that these projects align with the Dubai Government's strategy. It is highly recommended that the future prototype should be mixed-use, respond to the growing needs of the economy, and achieve the highest possible energy rating. Future research directions have also been pinpointed.

Keywords Sustainability, High-Rise, Design Trend, Green Building, Dubai

1. INTRODUCTION

Awareness of the diminishing oil reserves in Dubai has led to drastic measures being made by the Dubai Government to diversify their economy [1]. This resulted in a focus on tourism, business and trade, which required an unprecedented government commitment and investment, to ensure the success of this strategic decision [2]. Numerous strategies were employed by the Dubai Government to stimulate the economy and therefore achieve their new objectives. These included the construction of the first seven star hotel in the world - Burj Al Arab, free business zones being made available to global companies and the opportunity for foreigners to purchase real estate [3]. Jana [4] describes this directional change as a period of time where Dubai was seeking to achieve world records; having the tallest, largest and when possible, the first of everything.

However, the global financial crisis has prevented Dubai from continuing construction at this phenomenal rate. Smith [5] highlights the fact that Dubai is $80 billion in debt, which is preventing the opportunity to inject large amounts of money into the economy. Harman [6] further exemplifies this

matter highlighting large projects, such as the $600 million Trump Towers, has been suspended with a commencement date unknown. Furthermore, Murray [7] raises issues regarding newly built high rise towers, which have insufficient surrounding infrastructure, such as pedestrian access and in some instances no electricity supply.

Interestingly, Lachenmayer [8, p.19] raises the importance of the current global crisis. He explains it 'can be seen as a blessing in disguise for Dubai.' Lachenmayer [8] explores this idea further by noting during strong periods of growth clients / investors get held up in the concept of making record profits and avoid the real issues at hand. Therefore, this provides the opportunity to evaluate and strategically plan for the future, by learning from the mistakes made in the past. This notion has been observed by Murray [1] in Dubai; 'clients have begun asking for high quality, sustainable buildings, not just iconic, world record-breaking structures.'

Worldwide the construction industry uses 60% of the world's energy to heat, light and ventilate buildings [9]. Major contributors to this statistic are energy hungry high rise buildings in Dubai. Prior to the worldwide economic crisis, Dubai was striving to break as many records as it could in terms of the tallest, largest, or simply the first [4]. In recent times, the Dubai Government has identified the importance of sustainability and in doing so has realised that in order to make Dubai a world-class city in a true sense – the biggest polluter to the UAE's environment, the construction industry should be regulated [9]. This issue has been addressed in Dubai's Strategic Plan (2015) within the five guiding principles, in particular the 'Infrastructure, Land and Environment' principles and also with the BREEAM Gulf environmental assessment system.

Dubai's Strategic Plan (2015) presents the Government's vision and framework regarding how this is going to be achieved, however gaps appear in current research with reference to whether the future high rise design trends align with these principles. Research by professionals within the construction industry, have reviewed proposed future high rise projects in Dubai from a sustainability point of view, but failed to identify whether these design trends align with Dubai's Strategic Plan (2015). Further to this, no existing research presents a recommended high rise design trend for Dubai to employ. This presents a number of issues because in order for the Dubai Government to achieve these objectives and therefore be seen globally as a sustainable city, all governing bodies need to have a clear understanding of this Strategic Plan. This will ensure future high rise design trends not only meet these minimum standards, but the construction industry is encouraged to exceed these standards where possible. To achieve this objective a high rise design trend benchmark needs to be established, to allow a comparative analysis to occur.

This paper attempts to address the gap in current research, by providing justification as to whether the future high rise buildings align with the Dubai Government's strategy and to identify the most appropriate sustainable high rise design trends. The primary objectives of this paper include (1) investigate the problematic issues in the past methodology which Dubai adopted within the construction industry and how these issues can be mitigated in future projects; (2) examine the significance of sustainability to high rise building design trends; (3) explore how the five guiding principles of the Dubai's Strategic Plan (2015) will influence high rise building design trends; (4) explore how the BREEAM Gulf environmental assessment system will significantly influence high rise building design trends; and (5) analyze influential high rise towers in Dubai, which are currently or proposed to be built. After the introduction, this paper will review the literature on sustainable practice. It will then review the

Dubai Government Strategy towards Sustainability in detail, followed by case studies of Dubai high rise buildings. A detailed discussion will be presented before concluding remarks and recommendations for future research.

2. LITERATURE REVIEW

2.1. Sustainable High Rise Buildings

Within the construction industry there is still much confusion regarding what sustainability is. This is partly due to the fact that there is generally a lack of knowledge amongst professionals that sustainable practice is not financially rewarding. However, through a greater understanding of the benefits of implementing sustainable principles, this perception has caused many in the construction industry to re-evaluate their ethical and moral stance in seeking innovative pursuits with eco-effective results in mind.

Sustainability has many definitions but the basic principles and concepts remain constant: balancing a growing economy, protection for the environment, and social responsibility, so they together lead to an improved quality of life for ourselves and future generations [10, p.31]. Crompton and Wilson [11, p.3] explore the concept of sustainability further by providing a purist's definition of a sustainable tall building; 'one which emits no pollution to air, land and water, and can be economically occupied throughout its design life, whilst contributing positively to the local community.' Galbraith [12] raises the viewpoint that for the construction industry this purist's objective of sustainability is not feasible, however, encourages the industry to incorporate sustainable design where possible and in doing so have an understanding of how the building will impact the environment in both a positive and negative way.
In order to create a platform which allows innovative change and sustainable development, a series of basic principles need to be established. Material choice, orientation of the building to maximize solar gain, and a cradle to mentality in the way we build and manufacture building products, should all be employed as standard practice.

There are many benefits for clients, developers and owners in incorporating sustainable practice into a construction project. These benefits include significant reductions in green house gas emissions [13], increase in productivity by at least 30% [14], 5 to 10% reduction in cooling needs [15], a saving on average, 70% of electricity, between 50% and 60% of water, and 36% of energy when compared to the standard buildings [9], 30% reduction in light fixtures or light needs - critical when you consider that lighting can account for up to 35% of a building's energy and financial gain by commanding sale prices of 30% more on average when compared with other buildings[15].

2.2. Implementing 'Green' Objectives in Future High Rise Buildings within Dubai

To successfully implement green objectives in high rise buildings 'a strong understanding of existing conditions: environmental data, relationship to existing and future developments, and the policies in place that support site development' [15] must be achieved. Gill [15] further details this process stating 'designers must understand and consider building orientation, opportunities for daylighting, generation of wind power, solar absorption and a site's geothermal properties.' Jahnigen [16] summarizes this concept convincingly by suggesting 'there is no 'one-size-fits-all' approach, as the development of a project is unique based on its surroundings.'

In reference to Dubai, one of the climatic conditions which must be identified and designed around includes the extreme heat where 'temperatures in summer average forty-five degrees, while in winter

they fall to 24 degrees' [17]. Consequently, 'ninety-five percent of all spaces [are] air-conditioned,' [17] to try and provide comfortable working conditions inside. Conradi [18] identifies that this climatic condition needs to be considered at the forefront of the design phase and identifies the opportunity to exploit this, by incorporating solar panels to generate electricity that can be used within the building.

3. THE DUBAI GOVERNMENT STRATEGY TOWARDS SUSTAINABILITY

3.1. Introduction

In the past decade, sustainable design and practice was not identified by the Dubai Government as a means for innovative and profitable outcomes [19]. This was largely due to the fact that clients, consultants and contractors were experiencing a period of substantial growth and stability in the construction industry. The mentality was simply to construct high rise buildings rapidly to try and meet the excessive demand by wealthy expatriates who were seeking instant profits and a life of luxury. Hence, sustainable practice was at best an afterthought, which was seen as an unnecessary expense for the client to invest in [20].

However, the recent global crisis has put enormous strain on the city of Dubai, which has been forced to seek alternative approaches to stay insulated during these tough times. A collaborative approach seeking innovation through sustainability has recently been understood and acknowledged to produce positive outcomes, not only the client and project team, but also the occupants of the building. This understanding has been presented within the Dubai Strategic Plan (2015) and also in the BREEAM Gulf environmental rating system for construction professionals to adhere to.

3.2 Dubai Strategic Plan (2015)

The Dubai Strategic Plan (2015) was announced by His Highness Sheikh Mohammad Bin Rashid Al Maktoum, UAE Prime Minister and Vice President, and Ruler of Dubai, on the 3rd of February 2007. This document details the strategic approach to develop the emirate's most dynamic economic sectors and was launched by His Highness Sheikh Mohammad Bin Rashid Al Maktoum under the theme of 'Dubai...Where The Future Begins'. Maktoum [21, p.9] clearly presents within the Dubai Strategic Plan (2015) the aim, which is 'to establish a universal understanding of Dubai's vision among the various government entities and to ensure a common framework for the operations of these entities.'

In order to achieve this aim, five guiding principles have been identified within the Dubai Strategic Plan (2015), including (1) Economic Development, (2) Social Development, (3) Infrastructure, Land and Environment, (4) Security, Justice and Safety, and (5) Government Excellence [21]. The guiding principle which addresses sustainable development is the Infrastructure, Land and Environment. The aim of this guiding principle is 'to ensure proper focus on sustainable development within the context of Dubai's considerable economic growth' [21, p.32].

In order to further explore and detail this guiding principle, four strategic trusts, which outlines how this vision will be achieved, have been presented, including (1) Optimize land use and disruption while preserving natural resources, (2) Provide efficient energy, electricity and water supplies to meet Dubai's growing needs, (3) Provide an integrated roads and transportation system to facilitate mobility and improve safety, and (4) Maintain Dubai as a safe, clean, attractive and sustainable environment [21, p.33]. Within each of these strategic trusts, the document further details these and highlights the requirement to optimize land use, secure both in the short and long term natural resources, develop the

transport infrastructure, continually update green building regulations and promote sustainable practice.

3.3. New Green Building Rating System for Construction in Dubai

Until recently, the only green building rating system used in Dubai was the US Green Building Council's (USGBC) LEED certification. However, this new acknowledgement regarding the importance of implementing sustainability has resulted in, 'BRE Global [launching] BREEAM Gulf, a regional adaptation of the UK standard' [22]. The aim of BREEAM Gulf aligns with the UK standard, which is to identify the various building types and following this allow assessors the right framework to evaluate the building's environmental credentials [23]. This assessment can occur during the design stage and/or during the post-construction stage and can be undertaken for new buildings, major refurbishments and new build extensions [24].

In contrast, BREEAM Gulf 'evaluates the performance of a whole building taking into account the different uses' [23] such as commercial and residential use. The significance of this is to reflect on the common building types in Dubai, which is mixed-use. BREEAM Gulf contains the same categories from the UK BREEAM which includes Management, Health and Wellbeing, Energy, Transport, Water, Materials, Waste, Land Use and Ecology and Pollution [24]. Within each of these categories, numerous criteria's are assessed via rating benchmarks and environmental weightings, to determine a section's score, which when added together provides a total score [24]. This total score then indicates a star rating, which reflects how environmentally friendly the building is. An example of the BREEAM Gulf rating benchmarks along with the score and rating calculation is shown in Table 1 and Table 2.

Table 1 BREEAM Gulf Rating Benchmarks [24]

BREEAM Rating	% score
No stars	<30
•	≥30
• ••	≥45
• •• ••	≥55
• •• •• ••	≥70
• •• •• •• •• •	≥85

Table 2 BREEAM Gulf Score and Rating Calculation [24]

BREEAM Section	Credits Achieved	Credits Available	% of Credits Achieved	Section Weighting	Section score
Management	7	10	70%	0.08	5.60%
Health & Wellbeing	11	14	79%	0.15	11.85%
Energy	10	21	48%	0.14	6.75%
Transport	5	10	50%	0.05	2.50%
Water	4	6	67%	0.30	20.1%
Materials	6	12	50%	0.09	4.5%
Waste	3	7	43%	0.05	2.15%
Land Use & Ecology	4	10	40%	0.07	2.8%
Pollution	5	12	42%	0.07	2.94%
			Total Score		59.19%
			BREEAM Rating		• •• ••

Upon review of the BREEAM Gulf score and rating calculation, the water section is weighted the heaviest at 30%. Standen (cited in Hartman [22, p.36]) emphasis the significance of water to the area by explaining 'most portable water in the Gulf is provided through the desalination of sea water, a process which (...) is 10 times more energy intensive than providing a litre of water in the UK.' Furthermore, the other heavily weighted categories; health & wellbeing – 15% and energy – 14%, will also significantly influence the high rise design trend prototype and therefore must be considered at the forefront during the design phase of a project. Willis (cited in Hartman [22, p.35]) reflects on both rating systems and suggests that 'both rating systems are doing the right thing, which is to reduce energy loads in buildings.' Others however, may argue that BREEAM Gulf should be Dubai's preferred rating system because it addresses 'the region's climate, regulations and construction practices' [22].

3.4. Further Discussion

Dubai, until recently, has experienced unprecedented levels of construction and consequently energy hungry and sick buildings have been built. In contrast today, sustainability has been considered at the forefront during the design phase of projects. Lander, Head of Sustainability at Atkins Dubai, reiterates this notion further by stating the sustainability agenda has 'exploded' in the last six months [22, p.35]. Johnson, a Gensler Managing Principal further strengthens this viewpoint commenting Dubai is picking up on messages from around the world, and one of those is sustainability, and they have the ability to implement it. However, research conducted by Marashi and Bhinder [9] has identified that the real challenge lies in integrating this growth and development with sustainable solutions that have long-term effects.

4. DUBAI HIGH RISE BUILDING CASE STUDIES

High rise buildings consume large amounts of energy. They are the most influential type of structure, due to their size and function and consequently must be seen by the construction industry as the platform where sustainable design must be showcased [25]. In this section, three case studies are presented in an analytical approach to examine and understand Dubai's strategy towards sustainable high rise design trends in the construction industry. Case study No. 01 examines the functional use design trends in high rise buildings used today and identifies which type is most commonly used. Case study No. 02 outlines how high rise building design trends have continued to develop allowing greater heights to be achieved. Case study No. 03 presents a world breaking sustainable high rise building concept, which will influence high rise design trends worldwide.

4.1. Case Study No. 01 - Future Functional Use Trend

High rise towers can be classified into three functional use categories; commercial, residential and mixed-use. Binder [26] states that the mixed-use tower is now replacing the typical corporate office tower. This evolution has been reiterated by the Council on Tall Buildings and Urban Habitat (CTBUH) following research conducted which illustrated on the tallest 100 buildings lists from 1930 to 2000 [27]. The percentage of office towers was never below 86% whilst down to just 46% by 2010 [27].

Binder [26] suggests that this evolving trend may be a result of the enormous levels of construction which has occurred recently, leading to a shortage of tenants to fill commercial high rise towers. Furthermore, Binder [26] explains tourism is fast becoming an influential economy as hotels are becoming the major tenants of the new millennium. Research conducted by Gill [15] identifies the potential within mixed-use towers to foster a symbiotic relationship between different programme

elements, while the office space demands the heaviest energy load during the day, the hotel's usage is heaviest at night. Gill [15] explores this concept further by identifying through the use of an 'intelligent energy system' automatic programming can occur, ensuring that air-conditioning is only provided to those spaces which are occupied. This will result in an increase in the tower's energy efficiencies, along with balanced communities that work in symbiosis with one another.

Samarai and Qudah [14] extend upon Gill's understanding identifying the aim of mixed-use development is to have a community that is self-serving without the need to go anywhere else for anything. People will live, work and play all in the same place. High rise towers currently under construction in Dubai are predominately residential and mixed-use types. An example of a residential tower is the Pentominium Tower, which is set to become the 'the tallest all residential building in the world [at 615 metres], and is configured to provide one owner per level over its 120 occupied upper levels' [28]. The current most influential mixed-use tower examples are the Burj Dubai, its adherent the Nakheel Tower and also the Dynamic Tower.

4.2. Case Study No. 02 - Tallest Building in the World

4.2.1. Burj Dubai

The tallest building in the world currently is the Burj Dubai, which has been completed recently. This mixed use tower contains retail, offices, residential apartments, and a hotel and seeks to exhibit Dubai's vision to set world benchmarks within the construction industry. In making this project a reality, one of the critical issues the design team had to resolve was regarding how to reduce and control the wind forces on the tower. The design team's solution to this issue was a tri-axial 'Y'-shaped plan, where each tier of the building sets back in a spiral stepping pattern up the building (see Figure 1). This concept allows the facade to 'confuse the wind' because the wind vortices never consolidate with one another, due to the evolving building facade [29]. This shaped floor plan has other advantages such as providing 'an ideal arrangement of residential units, having an optimal plan depth-to-perimeter ratio and allowing maximum views outward, without overlooking a neighboring apartment' [30].

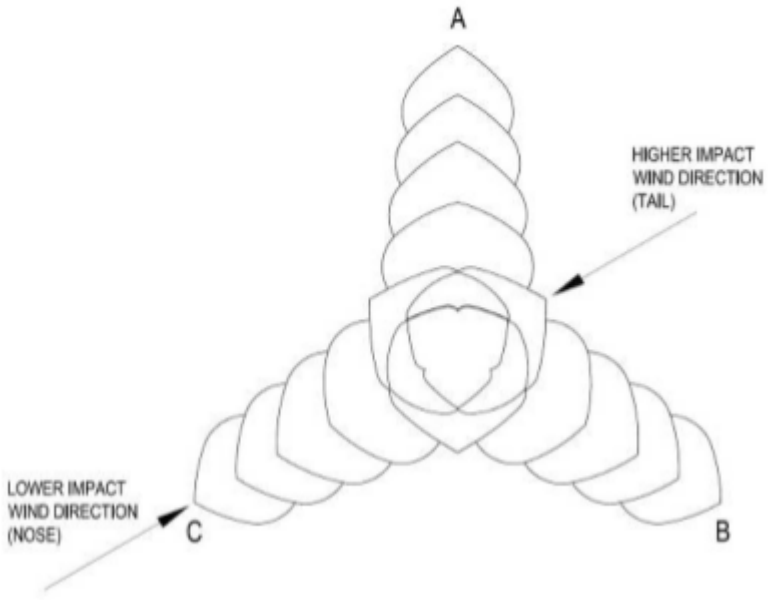

Figure 1. Burj Dubai Floor Plan [29]

4.2.2. Nakheel Tower

The adversary of the Burj Dubai, which will claim the world's tallest building when completed in the near future is the Nakheel Tower, which will stand over one kilometre tall. Unlike Burj Dubai, the design team for the Nakheel Tower is aspiring to achieve LEED Gold rating via numerous ESD initiatives, and in the process challenges the current model of what a sustainable tower should encompass, whilst providing the industry with the perception that the sky is the limit [31]. Achieving this world breaking height resulted in further research and analysis being undertaken, based on the lessons learnt from the Burj Dubai, along with the implementation of innovative sustainable principles. The design concept employed involved separating the tower into four stand alone towers, which were connected via skybridges at every 25 levels. Therefore, wind could pass through the building allowing the typical tampering of high rise tower floor plates was avoided (see Figure 2). This sustainable solution provides larger than normal floor plates at the upper levels, resulting in greater return in investment being achieved.

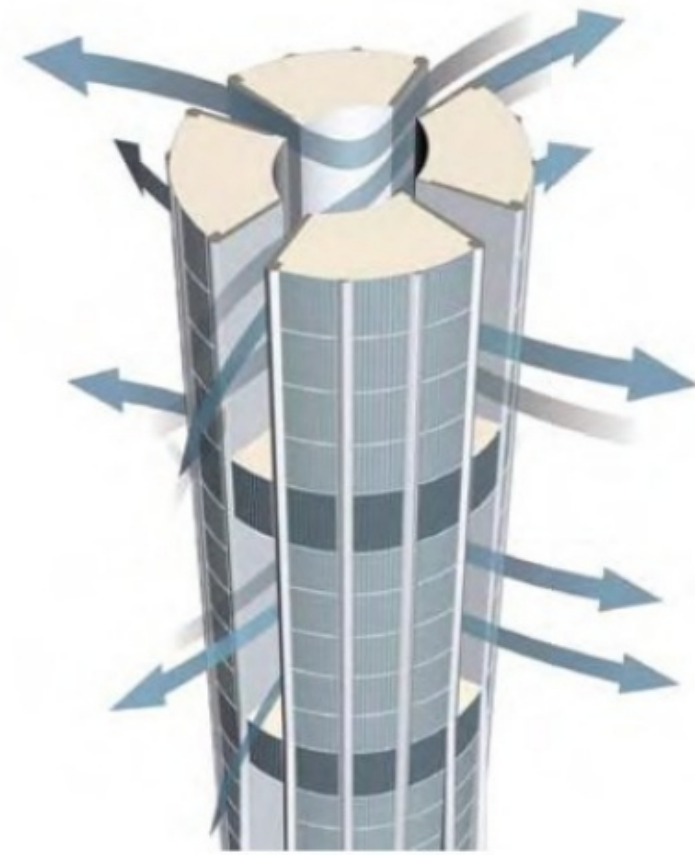

Figure 2. Perspective view of the Nakheel Tower illustrating how the wind passes through [31]

In further comparison to Burj Dubai, the Nakheel Tower also contains retail, offices, residential apartments and a hotel, however, further to this also contains an experience centre and observation facilities along with a special sky function space – creating a vertical community of over 15,000 people (see Figure 3). This new concept of sky bridges serves multiple purposes such as providing community and public spaces where visitors and residents alike can interact, whilst joining the four separate towers together and allowing transfer points between lifts [31].

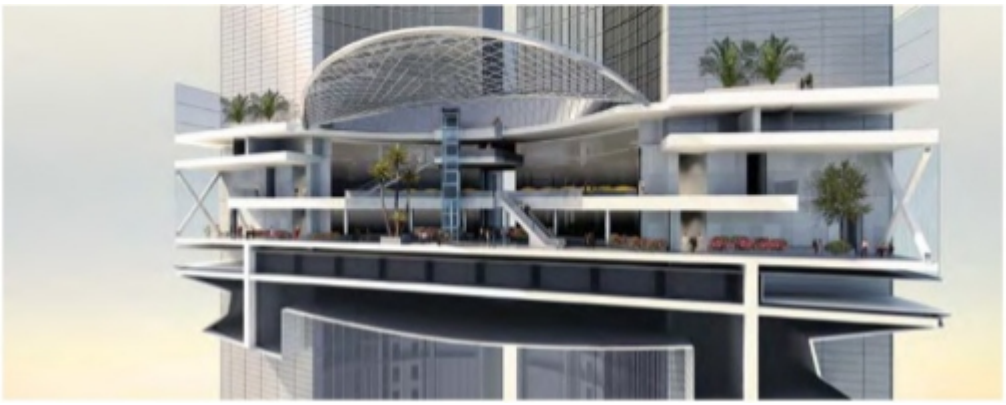

Figure 3. Nakheel Tower Sky Bridge Section [31]

4.3. Case Study No. 03 - World Breaking 'Sustainable' Design Concept

Pioneering architect Dr Fisher from the Florence based Dynamic Architectural Group, has created a world breaking concept involving a high rise tower's facade, which constantly rotates (see Figure 4). The Dynamic Tower is 80 floors high and is a mixed-use development containing offices, residential apartments and a hotel. This construction procurement method is unique to the construction industry as it will be the first factory-built skyscraper [32]. It will be made possible by constructing only the building's central core on site, which contains the buildings vertical transport system and services, while the remainder of the structure is prefabricated in a factory in Italy [33]. Each apartment is integrated within a prefabricated module, which is completely fitted out and only requires owners to move their furniture in [32].

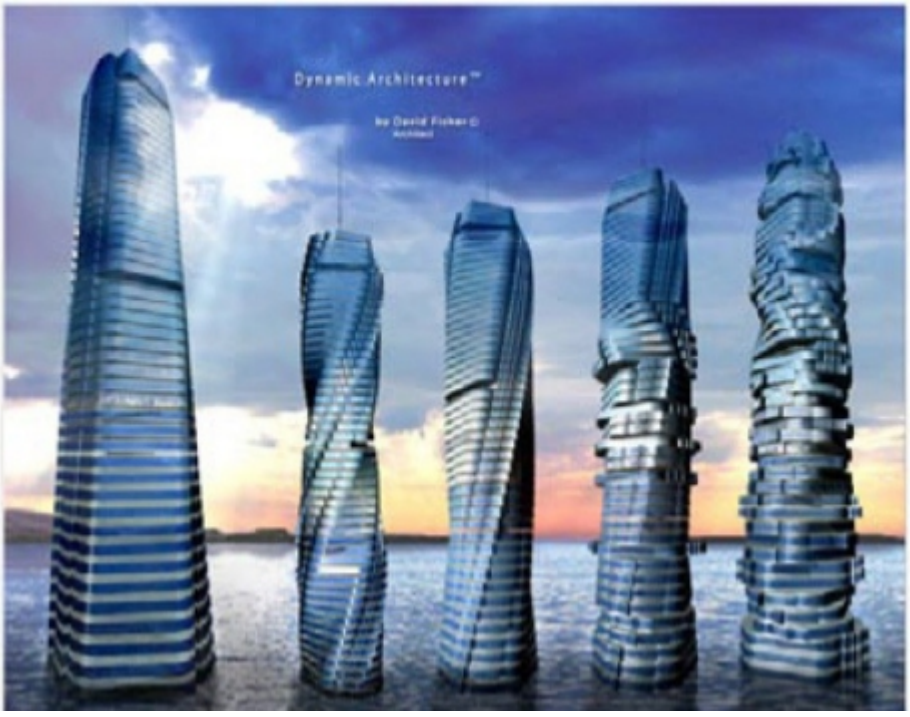

Figure 4 Dynamic Tower Rotating (Fisher [34])

Chamberlain [33] highlights some advantages of this procurement method stating designers estimate that the prefabrication approach should cut construction time from 30 months (for a traditional build) to 18 months. Furthermore, an estimated 90 employees will be required on site and an additional 700

employees in the factory, in comparison to over 1,000 employees for a typical project of this size on site [33]. However, although these factors present potential cost savings for the project, it is believed the tower in Dubai will cost around $330m. This significant cost can somewhat be justified by the investment in advancing today's technology in high rise developments, whilst ensuring a sustainable concept is projected. Fisher further discusses this issue stating the Dynamic Tower will be so energy efficient it will have enough surplus to power five similar-sized buildings [34]. This is achieved by large photovoltaic cells installed on the roof, along with 48 carbon fibre wind turbines which are positioned between each of the 80 levels [33].

Chamberlain [33] analytically raises a number of possible problematic issues regarding this design concept. Firstly, as the tower constantly rotates how can a reliable power and water supply be provided? Robertson (cited in Chamberlain [33]) who is the structural engineer for the project, explains supplying power to the apartments is based on 'the (...) same [principle] as that of a moving train gathering power from a third rail or an overhead line (...) [and] many appliances (...) [will] get power wirelessly. Furthermore, Robertson (cited in Chamberlain [33]) explains water supply will be provided through a sprinkler system via a 'flex connector, like a fire hose, and (...) [occupants] will plug it in when (...) [they] want to take water in.' In summary, Fisher [34] claims that the Dynamic Tower is the 'first real green building' because no building before has been designed to produce much more energy than it can use.

5. DISCUSSION

Development in Dubai prior global economic crisis was occurring at unprecedented levels, which Abdellatif (cited in Marashi & Bhinder [9]) comments was 'too fast for Social Structure, too fast for Infrastructure, too fast for the people, too fast for the environment and too fast for (...) [Dubai] to learn from (...) [their] mistakes.' This has resulted in Dubai adopting a more sustainable approach ensuring that future generations understand and therefore continue to implement sustainable development.

5.1. Critical Analysis of the Dubai Government Strategy

For any city worldwide 'taking up the cause of sustainable development is a big task, which requires vision, sound plans and most of all commitment at all levels' [9]. The Dubai Government has certainly taken important measures to implement sustainable development by detailing this approach within the Dubai Strategic Plan (2015) under the section Infrastructure, Land and Environment and also by encouraging the use of environmental rating systems LEED and the newly created BREEAM Gulf. Another implementation included the formation of the Emirates Green Building Council in 2006. The success of this congress was reiterated by Seneviratne (cited in Hartman [22]) who claims 'almost 1,000 engineers, architects and other construction professionals in the UAE have trained as LEED (...) [accredited professionals] (...) [during 2007 – 2008].' Along with this initiative a number of 'free zones have adopted LEED Silver or Gold as a minimum standard for development' [22]. However, this is yet to be implemented for BREEAM Gulf.

Marashi and Bhinder [9] interestingly suggest that the Dubai Government has the precise framework in place to achieve sustainable development and accordingly it is now the responsibility of the relevant committees, clients, developers and consultants to ensure this is made a reality. This viewpoint can be challenged upon close review of the Dubai Strategic Plan (2015). Critics would question why the Infrastructure, Land and Environment guiding principal is not presented first, ahead of both the Economic Development and Social Development guiding principles. By presenting this section first, it

illustrates Dubai's commitment of prioritising sustainable development to achieve both economic and social development. Further analysis of the Infrastructure, Land and Environment guiding principal section uncovers universal aims, such as 'maintain Dubai as a safe, clean, attractive and sustainable environment' Maktoum [21, p.32]. Furthermore, this aim could have included measurable objectives outlining a percentage of annual carbon emissions targeted, along with the enforcement of a minimum environmental rating for both the LEED and BREEAM Gulf applied to all new construction.

Maktoum [35] presents a similar argument against Marashi and Bhinder emphasising the importance of constantly reviewing the Dubai Strategic Plan (2015) to ensure this aligns with the current economic conditions. It is pointed out that due to the global financial crisis, the Dubai Government is in the process of reviewing all the developments in the financial markets and the global economy and will revise Dubia's Strategic Plan accordingly [35]. This strategy will ensure that where required, the objectives and timelines contained within the Dubai Strategic Plan will be adjusted to ensure these are obtainable.

5.2. Future High Rise Design Trend Recommendation

High rise towers of the future must not merely be measured by total height, instead its efficiency and impact on the environment will indicate how successful the development has been [30]. Research carried out to date, indicates how future high rise design trends will encompass the mixed-use prototype. This works in unison with Dubai's urban planning scheme involving creating 'cities within a city' [14]. Projects such as the Burj Dubai, the Nakheel Tower and the Dynamic Tower all attempt to exemplify sustainable development and achieve varying levels of success. Hence, analytical criticisms of each of these developments can be made to further understand the future high rise design trend Dubai should be inspiring to.

Weismantle et al. [30] question whether 'the Burj Dubai [is] an evolution based on designs that have come before it, or is it a revolution in design, more significant for more than just its unprecedented height?' Most critics would agree that it is both because extensive research has been undertaken to allow this concept to be developed and made possible, whilst challenging the industry to further develop this prototype.

The Nakheel Tower successfully attempts to challenge the world breaking achievements made by the Burj Dubai. Innovative sustainable practices have been employed, which reduces its carbon footprint. The matter which was not discussed in any of the research papers published was the fact that a tower of this nature and size can only be attempted occasionally. Enormous investment is required by developers, which must be validated by market interest and investment. A LEED platinum rated high rise tower will not be seen as a sustainable solution, if the tower is occupied at 40% capacity.

Furthermore, the Dynamic Tower presents an arrangement of sustainable initiatives never attempted previously. Whilst adopting this strategy, new questions need to be asked and consequently answered by the Dynamic Architecture Group. How reliable will the wireless power supply be during desert storms? How environmentally friendly is transporting these apartment capsules from Italy?

In review, all three prototypes; the Burj Dubai, the Nakheel Tower and the Dynamic Tower align with the Dubai Strategic Plan (2015), in particular, the guiding principle - Infrastructure, Land and Environment. Each development provides community facilities, promotes sustainable practice, exhibits energy efficient solutions, optimises land use and reduces strain on the existing transport

infrastructure [21, p.33]. As discussed, each of these prototypes has issues which require to be addressed. Accordingly, Dubai has not discovered their high rise model which reflects the high rise design trend of the future. This can be achieved in the near future through evaluating and further developing the existing design trends proposed today. Based on research conducted to date, the future prototype should be mixed-use, achieve the highest possible energy rating (LEED or BREEAM Gulf) and 'reduce the human impact on the environment' [31].

6. CONCLUSION AND RECOMMENDATIONS

The current global economic crisis has led to individuals, companies and governments to consider innovative approaches to secure their position within the construction industry. With the recent uncertainty as to the full impact of the global economic downturn, the construction industry in Dubai is being forced to consider more than just profitability, but to also establish a response which increases activity strengthening the economy. This has been achieved by setting clear and distinct objectives and values, to ensure all members of the industry remain focused during this difficult period. A newly adapted rating system BEEAM Gulf has been released and currently the Dubai Strategic Plan (2015) is being revised to further detail Dubai's strategy towards sustainable development in these challenging times. By establishing these principles, members within the industry can contribute their knowledge and energy toward[s] creating a prototype for greening tall buildings'. This future high rise design trend will encompass a sustainable mixed-use approach, which responds to the growing demands of the economy through the implementation of intelligent ESD initiatives, resulting in a 'green' high rise tower solution.

Further research could examine sustainable high rise design trends outside of Dubai and determine whether Dubai can implement some of these sustainable practices, to further improve their sustainable high rise prototype. Additional research methodology could be employed to obtain additional primary data via a questionnaire which would be completed by professionals in the construction industry. These results would be populated and allow further discussion to take place and refinement of Dubai's sustainable high rise prototype.

REFERENCES

[1] C. Murray, Dubai, The Architects' Journal 228(21) (2008).
[2] M. Matly and L. Dillon, Dubai Strategy: Past, Present, Future, 2007. [Available online from http://belfercenter.ksg.harvard.edu/files/matly_paper1.pdf.].
[3] R. Ivy, Topping Out, Architectural Record 197(2) (2009).
[4] R. Jana. Dubai's Architectural Wonders, In Business Week Online, 2 March, 2006, 2006. p. 18.
[5] P.A. Smith, Uae Faces Global Headwinds to Emerge Stronger, The Middle East (April) (2009).
[6] D. Harman. Foreigners in Dubai Hit by Downturn, In USA Today, 5 June, 2009.
[7] C. Murray, Dubai Grows Up, The Architects' Journal 228(21) (2008).
[8] J. Lachenmayer, The Future of Dubai, SE Group, 2009, p. 1-24. [Available online from http://www.segroup.de/en/news/170-paper-on-the-future-of- dubai.].
[9] H.A. Marashi and J. Bhinder, From the Tallest to the Greenest - Paradigm Shift in Dubai, in: A. Wood (Ed.), Proceedings of the CTBUH 8th World Congress - Tall & Green: Typology for a Sustainable Urban Future, (3 - 5 March, Dubai, UAE, 2008).
[10] R. Sherar (2008) In Rock Products, pp. 28-31.
[11] A. Crompton and A. Wilson. Sustainable Tall Buildings - Fact or Fiction?2009. [Available online from http://www.cibse.org/pdfs/Ant%20Wilson.pdf.], accessed in November 2009.
[12] K. Galbraith, Structural Sustainability in the Gulf - Fact and Fiction, in: A. Wood (Ed.), Proceedings of the CTBUH 8th World Congress - Tall & Green: Typology for a Sustainable Urban Future, (3 - 5 March, Dubai, UAE, 2008).

[13] G. Battenbough. New York Icon Reveals Its Retrofit Secrets.2009. [Available online from http://www.architectureanddesign.com.au/article/New-York- icon-reveals-retrofit-secrets/476187.aspx.], accessed in November 2009.

[14] M.A. Samarai and L.M. Qudah, Planning Sustainable Mega Projects in Uae, in, Proceedings of the World Housing Congress 2007 on Affordable Quality Housing (WHC2007), (1 - 5 July, Primula Beach Resort Hotel Kuala Terengganu, Malaysia, 2007).

[15] G. Gill, A Tall, Green Future, The Structural Design of Tall and Special Buildings 17(5) (2007).

[16] C. Jahnigen, Making an Impact: An Integrated Sustainable Design Approach Can Lower Facility Ownership Costs and Establish More Productive Learning Environments, American School and University (2007).

[17] C. Bosse, The Injection of Building Culture into the Construction Boom - New Architecture in Dubai, Architecture and Urbanism 440 (2007).

[18] P. Conradi. Eco Home Projects Get the Green Light, In The Sunday Times, 14 December, London, UK, 2008.

[19] S. Bagaeen, Brand Dubai: The Instant City; or the Instantly Recognizable City, International Planning Studies 12(2) (2007).

[20] ENR, Time Is of the Essence in Building a Sustainable Future, Engineering News Record (ENR) 260(9) (2008).

[21] M.b.R.A. Maktoum, Highlights Dubai Strategic Plan (2015), 2006. [Available online from http://egov.dubai.ae/opt/CMSContent/Active/CORP/en/Doc uments/DSPE.pdf.].

[22] H. Hartman, Greening the Gulf, The Architects' Journal 228(16) (2008).

[23] BRE Global, Breeam Gulf, 2009. [Available online from http://www.breeam.org/page.jsp?id=196.].

[24] BRE Global, Bre Environmental and Sustainability Standard, 2009. [Available online from http://www.breeam.org/filelibrary/BREEAM_Gulf_2008_iss ue_2.0_0.pdf.].

[25] M.M. Ali and P.J. Armstrong, Overview of Sustainability Design Factors in High-Rise Buildings, in: A. Wood (Ed.), Proceedings of the CTBUH 8th World Congress - Tall & Green: Typology for a Sustainable Urban Future, (3 - 5 March, Dubai, UAE, 2008).

[26] G. Binder, The "International" Skyscraper: Observations, CTBUH Journal (I) (2008).

[27] CTBUH Journal, Tall Buildings in Numbers, CTBUH Journal (II) (2008).

[28] A. Davids, J. Wongso, D. Popovic and A. McFarlane, A Postcard from Dubai Design and Construction of Some of the Tallest Buildings in the World, in: A. Wood (Ed.), Proceedings of the CTBUH 8th World Congress - Tall & Green: Typology for a Sustainable Urban Future, (3 - 5 March, Dubai, UAE, 2008).

[29] W.F. Baker, D.S. Korista and L.C. Novak, Engineering the World's Tallest - Burj Dubai, in: A. Wood (Ed.), Proceedings of the CTBUH 8th World Congress - Tall & Green: Typology for a Sustainable Urban Future, (3 - 5 March, Dubai, UAE, 2008).

[30] P.A. Weismantle, G.L. Smith and M. Sheriff, Burj Dubai: An Architectural Technical Design Case Study, The Structural Design of Tall and Special Buildings 16(4) (2007).

[31] M. Mitcheson-Low, A. Rahimian and D. O'Brien, Case Study: Nakheel Tower - the Vertical City, CTBUH Journal (II) (2009).

[32] A. Pierce, The Dynamic Tower, Tech Directions 68(9) (2009).

[33] P. Chamberlain, The Da Vinci Mode, Engineering & Technology (6) (2008).

[34] A.D.H. Fisher, Rotating Tower Dubai, in: A. Wood (Ed.), Proceedings of the CTBUH 8th World Congress - Tall & Green: Typology for a Sustainable Urban Future, (3 - 5 March, Dubai, UAE, 2008).

[35] M.b.R.A. Maktoum, Prime Minister's First E-Session with the Public, 2009. [Available online from http://www.uaepm.ae/en/media/esessions/Public-e-Session-e n-010609.html.].

ISSN: 2332-1091

Process not Product: Arc, Hull's Architecture Centre

Chris Hay
School of Architecture, University of Lincoln, Brayford Pool, Lincoln, LN6 7TS, United Kingdom
*Corresponding Author: chay@lincoln.ac.uk

ABSTRACT

This paper discusses the Arc project in Hull. It takes the form of a case study of a building conceived from the outset as having no fixed final form or indeed permanent location. The first iteration of the building, designed by Niall Mclaughlin Architects, was completed in 2006 and houses the events space and offices for Arc, the Architecture Centre for Hull and the Humber Region. The project grew out of an initiative formed by collaboration between academics from the two local Universities, plus Community and Business representatives. The intention was that the organization would act as a catalyst for change, and raise architectural aspirations underpinned by an ethos that local people were experts in their own lives. Arc did this through a series of interlinked programmes including Design Review, and the Learning and Public Realm programmes. In addition the building hosted exhibitions, debates and workshops. This is a timely moment to revisit this project as the particular set of circumstances that enabled the building to be realized have already passed into history. Arc both as a building and as organization can now be seen as representative of a particular political and cultural moment in the UK, one that is now firmly over.

Keywords Architecture Centres, Relocatable Buildings, Regionalism, Participatory Design

1. INTRODUCTION

This paper explores aspects of the design and subsequent realization of Arc, the building that housed Hull's Architecture Centre. The term Arc in this context is an acronym and stands for Architecture, Regeneration and Community. It is used here both to describe the Architecture Centre as an organization and to describe the building that housed the organizations activities. It is the building rather than the organization that is the main focus of this paper. The building was realized in 2006 on a site in the city of Hull which is in the East Riding of Yorkshire, England, on the north bank of the Humber estuary some 24 miles (40km) from the North Sea. The building, commissioned by the charity which ran the centre, of which the current author was the way that it was. Nationally, CABE, the Commission for Architecture and the Built Environment, invited bids from interested local groups to research the viability of establishing an Architecture Centre in their local area. In response to this the founding members of Arc proposed an organization which would work closely with local communities of interest, be they schools, businesses, community groups, local councils, and the public in general in order to raise interest in the built environment generally and to foster, wherever possible, an appetite for quality in new design proposals of any kind. In parallel with the development of Arc as an organization came the chance to build and Arc duly became the first, and so far only UK Architecture Centre to commission a building for its own use.

2. CONTEXT

ARC was founded in 2003 and was one of twenty-two, at the peak, independent Architecture Centres that existed throughout the United Kingdom. The organization grew out of a local initiative whose members came from education, the University of Humberside (as was), in the form of the School of

Architecture, now part of the University of Lincoln and The University of Hull working together with the local Community Regeneration Company, Hull Doc, the Local Authority itself and Cityvision, the then Regeneration Agency. The organization's purpose was to raise the quality of the city and sub-region's urban design, architecture and public space and it did his through developing and delivering programmes and services designed to encourage people of all ages, and from all walks of life, to take an active interest in the architecture and built environment which surrounds them. [1]

2.1. Hullness

Each of the United Kingdoms Architecture Centres is different, they all respond in varying ways to the locations in which they work and one of the underlying ideas behind Arc was an attitude to people and to place. We took the view that Arc should engage with local people, and to engage with them where they live and to recognize that people are 'experts in their own lives'.[2]. We also believed that if any architectural propositions supported by Arc were to have lasting value or meaning they had to recognize that Hull was a particular place and that it is one that, despite its checkered history, or indeed because of it, possesses a strong sense of character and the particular. Having said that we were aware, as David Leather barrow has pointed out, that history cannot be simply appropriated. He observes that ' there are two ways of being mistaken about history: one is to see it as something outside of the present, what was and is no longer, and the other is to view it as something which constitutes the present, what we are now within. The truth of the matter is neither so far off nor so near. Similarly the present is neither so empty nor so full.' [3]. We were thus interested in questioning how a building designed today could or should relate to its place, to its physical setting, but also, and most importantly how it could be seen to be relevant to the people who lived there.

The structure of places, is not fixed however, for as Norberg- Schultz has pointed out, they change and adapt, but places or 'Stabilitas Loci ' do need, according to him, 'to preserve their identity over a period of time'[4] in order that they may be recognized. This interpretation of place inevitability implies a degree of stability and continuity, which were qualities that we knew that any building we commissioned could not in practice possibly have. It would inevitably be ephemeral and transient. The nature of the commission meant that the project would, like all buildings, have to contend with the seasonal circumstances of climate and the diurnal cycles of light and dark, but it also precluded the deployment of any of the more durable aspects of local building culture, such as brick or stone, which might normally be expected to enable a building to be recognized as being a part of the city that had commissioned it. The question that Arc had posed, firstly for itself and subsequently for its architect, was how should a temporary structure contribute to an existing environmental or architectural character and to this particular city and its many and diverse communities, when the very nature of the commission suggested that certain avenues were closed? The answer to these questions lay in McLaughlin's insight that the context for the project was not primarily a material one, important as that would be, but that it was societal, and if we started by engaging with the cities manufacturing base and listening to its people and their stories, we would find that an architecture capable of resonating with them would emerge out of these conversations, and if certain material or constructional strategies were precluded then this would enable the project to open itself instead to others equally potent in their relationship to local circumstances.

2.2. The Commission

The commission arose from the opportunity to house Arc's progammes by providing a flexible learning and exhibition space supported by offices and ancillary spaces for staff and visitors. We had access to

funds, which were themselves subject to time constraints, and we found that although we could build we did not have the resources to acquire and do so on a permanent site, and this meant that time would play a decisive role in both what and where as well as when something could be achieved. The resultant project had to negotiate the pragmatic and to exploit opportunities as they arose. We were fortunate that our inability to commission a permanent building fitted with our intention to take Arc to where the issues were and not rely always on the issues finding Arc. We were thus contemplating a mobile or moveable structure, which would, like a fair or a circus, move from site to site within the city as funds, and opportunities presented themselves. Thus the project from the start embodied change and processes of making, unmaking and remaking.

We had of course to start somewhere and, in partnership with Hull City Council, we examined underused or vacant land which the city owned and in due course Arc entered into a lease with them, granted on a peppercorn rent, for the use of a city centre site on the northern edge of the fruit market area adjacent to the A63 corridor which connects the city to its port but which also severs its connection with its waterfront and the estuary itself. The lease was granted on a temporary base and was and is subject to renewal or otherwise depending on the likely hood of redevelopment.

3. A PARTICIPATORY APPROACH

The appointment of an architect was done by means of a competitive interview. Arc invited a number of practices to propose an approach to the commission rather than possible design solutions to the brief. Niall McLaughlin was subsequently appointed partly on the basis of the approach that he outlined, but also because of his previous successful experience with working with school children on the design of his bandstand at the De La Warr Pavilion realized at Bexhill-on-Sea in southern England and completed in 2002. The design process began with a series of workshops that were arranged to be as inclusive as possible and to which people were invited who represented as many of Hull's diverse communities as we could engage with. The methodology adopted at these sessions was based on Participatory Appraisal (PA). This is a process that values local people as experts on their own lives and places, and which combines community research, learning and collective action. PA was first employed by British and Kenyan practitioners in rural communities in Africa [5] and two of Arc's board members, Susie Hay and Gill Hughes, who are trained PA practitioners, brought their expertise to bear in designing these sessions. According to Susie Hay, PA 'is not a scientific research approach, but looks rather to collect highly qualitative information relating to participants experiences, and perceptions of reality, to acknowledge issues and to plan for change' [6]. Sybille Manneschmidt has also argued that PA differs from more traditional extractive research methodologies in that 'group members are key actors. Their knowledge and experience is a basis for achieving understanding.' She goes on to say that 'as group members present and analyze their " own" data and define preferences and priorities towards a more developmental process for their community, information is not extracted from but rather is owned by the community'[7]. It was this sense of collective ownership of emerging issues that PA produced that was especially valuable to the design team and to local people who participated. Their success can be evidenced by citing the Rev Mike Hills, a local community leader who said 'this community has been consulted to death, we are asked out views on almost everything, and mostly nothing happens. Here, for the first time we can see how the communities concerns have been reflected in an actual proposal'. [8] Thus the design emerged from a process of parallel learning where as I have suggested earlier 'the architect and community representatives came together to exchange expertise (in order to) establish a sense of ownership by the community in the design.'[9] Of all the narratives that emerged from these sessions the loss of the cities connection with the sea because of the decline of its fishing industry and the

subsequent erasure or denial of these memories through a desire in the recent past to embrace a different future emerged as a touch stone for the project.

3.1. The Cup and the Saucer

We began the project with the knowledge that the building would move and of course most buildings don't move from the site of their construction. They are built, then inhabited,

altered, repaired, or otherwise and ultimately demolished, all in the same place. The land or the site on which they stand is, as Stewart Brand [10] has pointed out, the most permanent thing about them, and everything else is, even in the most lasting of structures, as Ed Hollis [11] has eloquently demonstrated in his exploration of the histories of the Parthenon, is susceptible to change in one way or another. McLaughlin's view of change was that it needed to be embraced, and his thinking here is close to Frank Duffy's [12] in his analysis of how time affects the various components and systems of commercial office buildings in different ways. Duffy has shown that the how, when and why of any change does not uniformly effect all aspects of a buildings fabric in the same way. Some aspects of buildings change far more rapidly than others as factors such as the difficulty or ease of altering something, the durability of materials and components, their accessibility, or otherwise, and the availability of resources, both material and economic all play their part in preserving, or otherwise, the various systems or layers which make up their being. Rather than seeing buildings as permanent, or "hardened into a temporal categories of order, and thought to be eternal and true" [13], an example of which one can see in Corbusier's white villas of the 1920's, which seem to deny the very existence of time and exist only, as it were, in a permanent present, unable, like Dorian Grey, to age. The Arc project actively embraces change and uncertainly and the creative possibilities offered by them.

McLaughlin's first ideas contained a powerful metaphor to describe the relationship between the building and its site, which he characterized as being like that of a cup and a saucer. The site here stands in for the saucer and the building for the cup. Mclaughlin was alluding to the way a cup is housed by its saucer and that when the cup is removed the memory of its presence is still seen in the depression left behind. Thus when the building is first moved an impression of its placement in the ground is left and a memory of its presence remains. This sensibility has phenomenological roots I would argue. Maclaughlin conjures an image of a vessel, a bounded container, a place for human interaction, located both in and on a particular place. This is an archetypal image for as Karl Bloomer and Charles Moore remind us 'the landscape of the inner world of landmarks, coordinates, hierarchies, and especially boundaries serves, we believe, as the only starting point for the organization of space around us, which more than being perceived, is inhabited by us'. [14]

3.2. Earthwork and Framework

Mclaughlin's instinct was to incorporate the very ground itself into the building. He proposed a lean-to structure, rectangular in plan, whose roof would rest on a long wall, a gabion filled with material directly taken from the site. The resultant interior volume would house all the necessary accommodation with the sloping roof forming the main elevation to the east and the wall the rear elevation to the west. This material and construction strategy takes us close to Gottfried Semper's understanding of primitive construction, which he developed after seeing a Caribbean Hut at the Great Exhibition of 1851. Semper proposed that the primordial dwelling was divided into four basic elements: the earthwork, the hearth, the framework/roof and the enclosing membrane. [15] Kenneth Frampton, refines this idea and suggests that, according to Semper, the buildings crafts can be understood as being essentially two fundamental

procedures, namely 'the tectonics of the frame combined with the sterotomics of the earthwork'. [16]. Thus we can see Mclaughlin seeking to create an enclosure which relates to what is below - the earth, on the one hand and what is above – the sky on the other. Edward Casey suggests that these are the 'separate protoregions of ordinary perception; they divide up the perceptual landscape from the beginning' [17] and I suggest that Mclaughlin here is referring, through his spatial and constructional strategy to shared perceptual understandings of the world and how buildings can be formed within it. In the event the earth wall did not survive into the final design proposal but its echoes can be seen in the red/brown coloration on the service pods in the computer images of the building (see fig 1.)

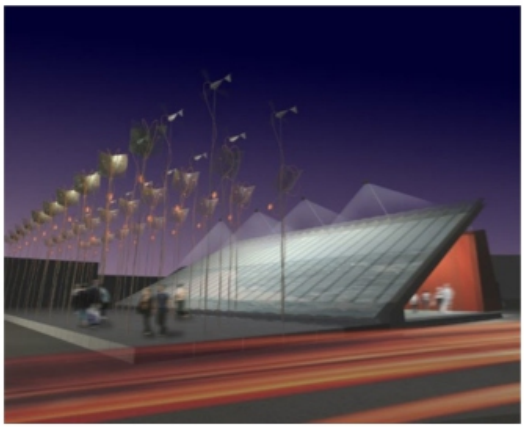

Figure 1. Night view in Context

3.3. The Building and Time

Mclaughlin proposed that Arc was not commissioning a building but a 20-year long narrative which, like all good stories, starts out somewhere, and after a number to twists and turns ends somewhere else entirely. He suggested a process of making, unmaking, moving and remaking where each iteration of the building becomes an opportunity to revisit the design and its components in order to see which are still relevant, appropriate or indeed obsolete and whither they need to be replaced or reconfigured in response to the possibilities presented by their new location. I would suggest that Arc as an idea can be best understood as a phenomenon which is time based, like film, where at any point in its existence one is experiencing it like a still taken from a stream of events, a moment in the story but not the whole picture itself. The question is not what Arc is but rather when it is. Arc it is a process not a product, and is in a continuous state of becoming.

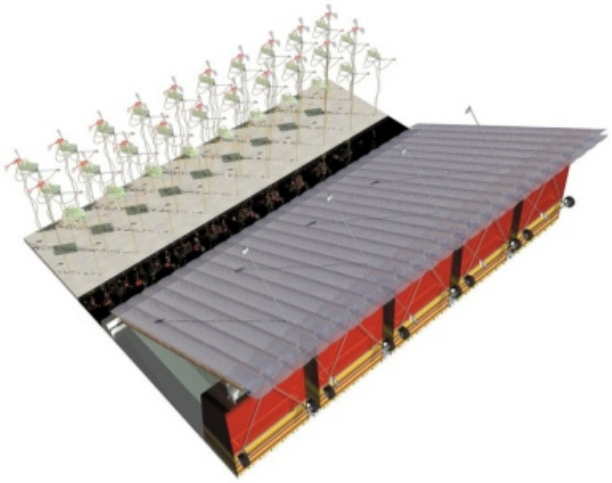

Figure 2. Axonometric from the rear

Before discussing the project as built it is pertinent to reflect on the relationship between the project as an idea and the project as a building. Like most architects today McLaughlin's office makes drawings, models and written specifications that are all, in some form or another, representations of the design. They in effect describe it in an ideal state – fixed as it were in the virtual space of the computer and thus standing outside of the processes to which the building they describe will itself be subjected. In contrast to this perfect state, however, the world that the building inhabits is not ideal it is itself fluid and uncertain. Thus for reasons such as the finite sums of money available, the time limits in which the various funding streams had either to be spent or lost, unexpected costs imposed on the project and normal contractual difficulties that affect any building project, the building as first realized does not conform in several respects to the design as projected in the architects drawings.

For example the Highways Agency were concerned that the buildings unusual shape would cause possible traffic accidents as drivers would be distracted and lose concentration as they approached it from the east. To counter this Arc had to commission, at some cost, an independent analysis of any likely risk and, by citing structures such as the London Eye or the Angel of the North and by demonstrating that they had no detrimental effect on passing traffic we were able to convince the Agency to allow the project to proceed.

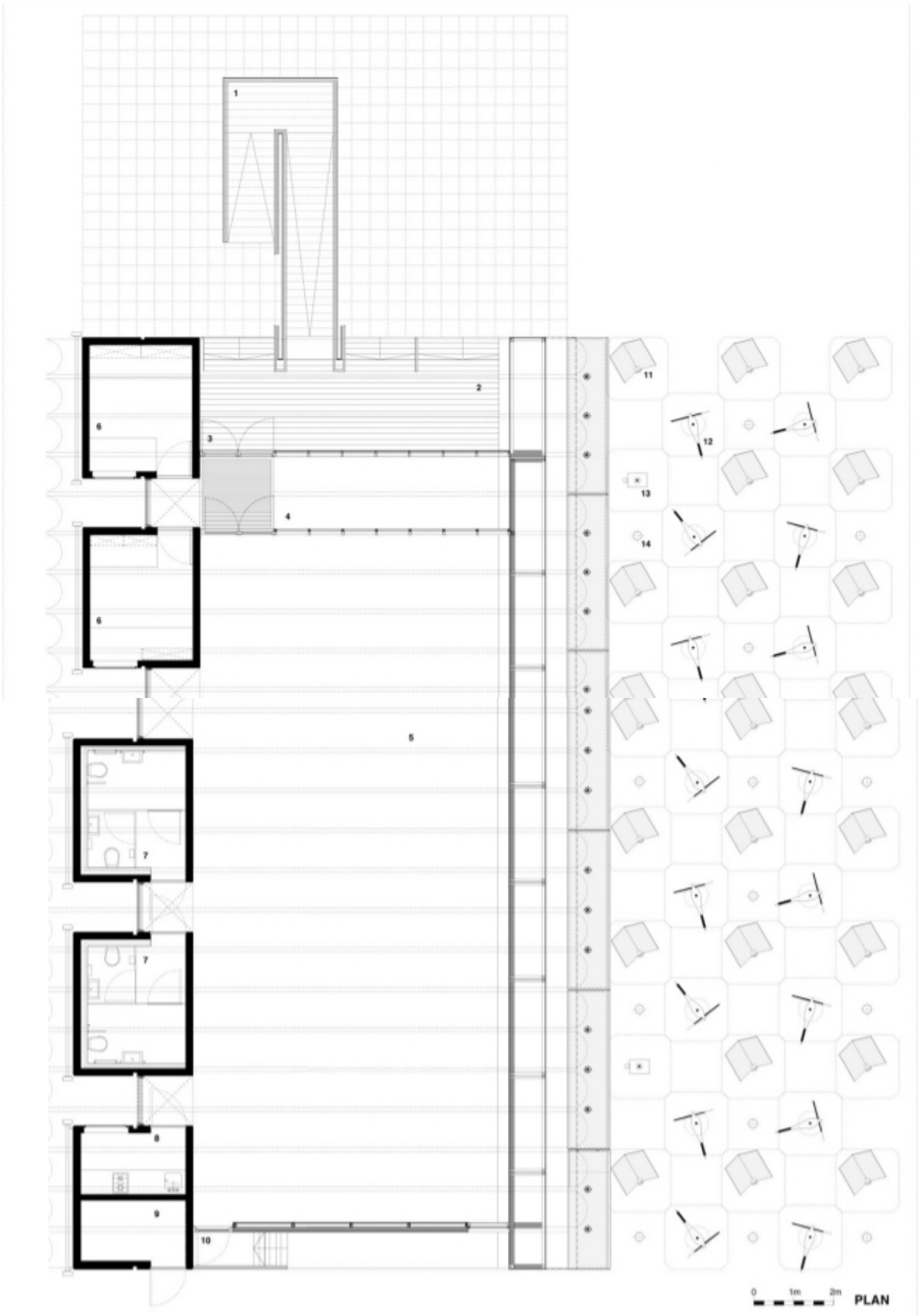

Figure 3. Plan

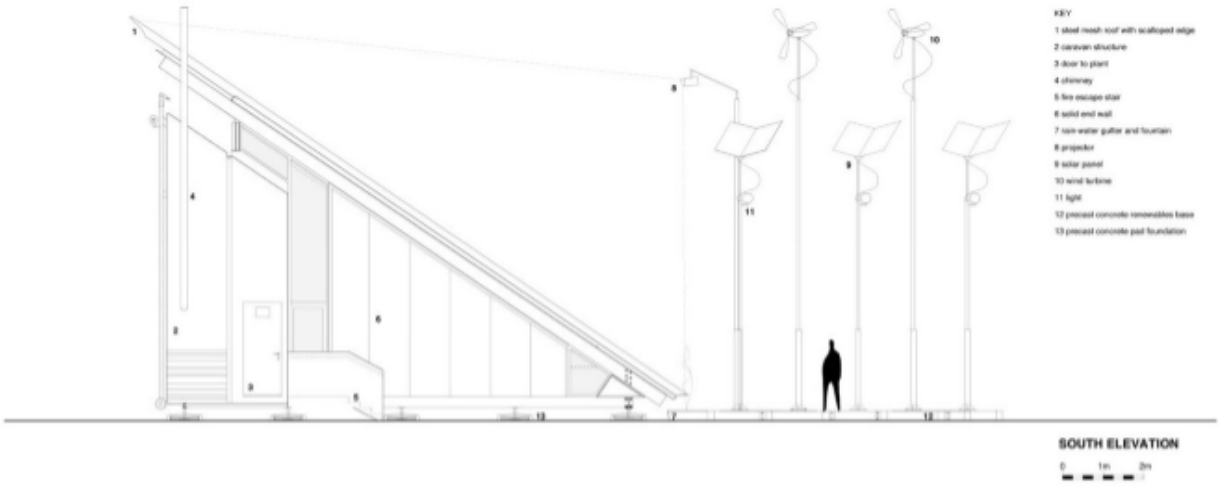

Figure 4. Elevation

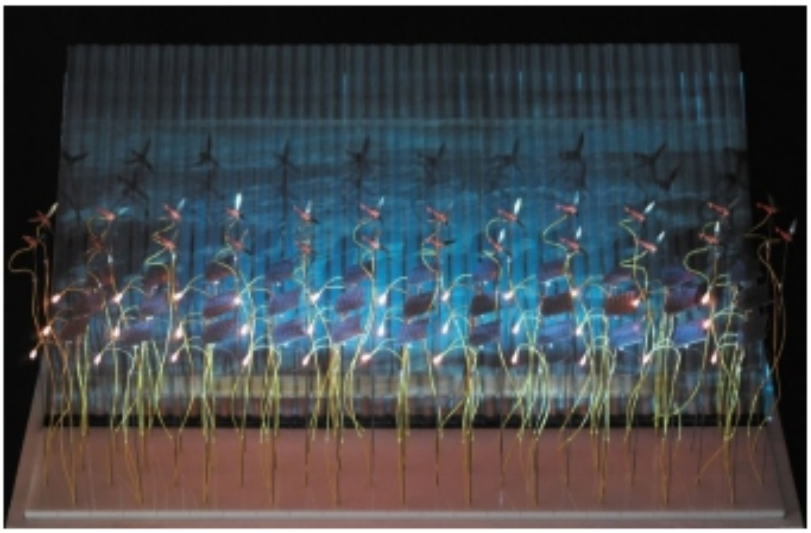

Figure 5. Model photograph of projection

Figure 6. East elevation

Thus aspects of the design were either amended or omitted altogether. The external assess ramp was redesigned and simplified, and the internal scalloped mesh ceiling panels and mobile storage wall were omitted altogether. These alterations in themselves did not seriously compromise the quality of the completed building as can be evidenced by the design awards it subsequently won and it can be argued that the loss of the ceiling mesh subsequently enabled an inventive appropriation of the ceiling plane as part of an exhibition on Hull's stories, see figure 7, which would not have been otherwise possible.

This disconnection between project and building illustrates that it is only in the world of the ideal, where as Edward Hollis has suggested, [10] things are perfect and therefore fixed; anywhere else they will be dynamic unstable.

Figure 7. Interior

3.4. The Project as Built

The brief asked for the provision of an adaptable space, one that could be used for exhibitions, meetings, workshops and events of various kinds and the resultant design accommodates this in a simple and straightforward manner. The interior is formed by an inclined plane that leans against a line of apparently upended blue caravans, or service pods, five in number. This creates a sheltered space akin to a den that a child might make by leaning some branches against a garden wall. Sitting directly in front of the sloping roof, which forms the main elevation of the building, is an array of solar panels and wind turbines, whose heads, like mechanical flowers are lifted and orientated towards wind and sun to make what McLaughlin refers to as a mechanical garden.

The resultant building is, I would argue syncretic in nature, and brings together a way of thinking about buildings which one can see in aspects of the work of Jean Prouve, for example in his exhibition pavilion for the Butagaz company at Nancy of 1953, or in the more recent work by Renzo Piano, as in his mobile exhibition building for IBM of 1982-84, where the building is conceived as a mechanism or machine. Located within a particular seam of modernist architectural thinking this 'high tech' way of approaching construction usually aspires to be as Kenneth Frampton points out, nothing more than 'elegant engineering'[18] with 'the corresponding victory of universal civilization over local culture'. [19] Here this generalizing tendency is countered with an interest in the specific akin to the practice of artists such as Susan Hiller, who according to Anne Gallagher ' combines objects and images from a variety of sources, to provide the viewer with an array of tantalizing fragments of cultural memory from which to form their own associations and meanings' [20].

The building is as much a product of local stormemories and about the land and the weather as it is concerned with manufacture and production. It is something which is capable of transformation and relocation yet deeply concerned with place and the particular characterizes of the local.

The sloping roof is orientated to the east and faces the incoming traffic arriving into the city over the river Hull. The plan, as yet unrealized, and now wholly dependent on the buildings new owners, was to use the roof like a roadside billboard and project images of the sea onto its rippled metal surfaces. McLaughlin's thinking, drawn form the earlier participatory workshops, was that at night the building would "dream about the sea and Hull's seafaring past "[21]

The building was designed to be dismantled, moved, then re-erected and its larger components are sized in accordance with vehicular dimensions to facilitate this process. The floor structure therefore comprises a series of steel cassettes, of standard road haulage width, filled with ballast, and subsequently bolted together. The outer roof surface is formed by a series of curved mesh aluminum panels which can, along with the translucent insulation panels which sit under them be easily lifted off and once this is done the steel beams which form the structure of the roof itself can themselves be dismantled. The 'caravans' are self-contained and can be moved short distances on their wheels and over longer distances on the back of a low loader. The building has no foundations as such and because of its low lying site and the possibility of flooding, sits on adjustable legs like a large piece of furniture, which lift it clear of the ground.

The building responds to its location through its orientation and the ways its surfaces work. The raised ground floor floats above the site because of flooding risk. It captures the wind and the sun through its array and it is naturally ventilated and cooled in the summer through exploiting its section and the cooling action of air passing over water. Its wood pellet boiler heats the floor in the winter and an even east light washes its interior through the inclined roof and a dramatic west light enters from between the caravan pods. The building also flexes, moves, and creaks in the wind and when the rain drums on its roof one feels in touch with the elements like being on a boat. From a phenomenological perspective the building is imbued with haptic and kinesthetic qualities. Additionally the building also responds to the larger context of the Humber through the thicket like nature of its energy gathering garden, and to the wider landscape of wetlands and reed beds that predate the cites foundation, and which still, in places, form the shifting edge of the estuary on which it stands.

Local industries also contributed to its form. Hull is a significant manufacturer of caravans and mobile homes and the design exploits this expertise and makes reference to this tradition, though in unsurprising ways. The five service pods, which contain offices, toilets, kitchen and plant are deliberately caravan like in their form but are used here as if upended. Their colour also makes reference to local memory and they are a deep blue because Reckitt's Blue pigment has been manufactured in the city since the early 19th century. The perforated aluminum roof panels, which form the external tilted screen, were made locally by a company which started out by making metal fish boxes for the local fishing industry and these are shaped to add strength and to channel rainwater off the roof and are scalloped to meet the sky in a manner analogous to other public buildings in the city. The wind turbines & solar array, which help define the building and give it presence, also take their place amongst the plethora of road signs and security cameras which are found around the site and, despite its uncompromising and surprising shape, allow it to become just another element in the everyday urban furniture of the city, a product of contemporary building technology, but also a product of Hull.

4. ARC IN USE

Since the building opened Arc has made an important contribution to local and regional debates on design quality thorough engaging with people from all walks of life, from school children, the general public and built environment professionals alike in a variety of different settings and occasions. Arc has delivered an education programme which has worked with over 150 regional schools, it has mounted a variety of exhibitions, both in the building and off site on topics such as Drawings Boards and East meets West – Exploring Hull's heritage and it has run an annual series of open lectures. It has worked with Hull City council to deliver the cites Public Arts Programme and has, through the mechanism of Design Review offered independent advice on over 80 proposed developments in the city and region. [22]

4.1. After Arc

This contribution to the cites recent cultural life and of the use of the building in its capacity as home to the centre's activities came to an end however on 15th May 2013 with the closing of the building and of the charity that brought it into being. This event can be seen both as a loss to the City of Hull and to Humberside generally and as an example of the national retrenchment which has occurred since the election of the Conservative Liberal Democratic coalition government in 2012. Thus Arc, both as an organization and as built form can be said to represent a particular political and cultural moment in the United Kingdom where central government, working through regional development agencies, in this case Hull City Vision and Yorkshire Forward, had the capacity and the desire to support regional initiatives, such as Arc in their aims to engender local interest in, and to act as a catalysts for, positive change in the built environment. This is a period which can be said unfortunately, as being now firmly over.

Arc was born under what was called New Labour. It was supported by CABE, The Commission for Architecture & the Built Environment, the local regeneration agency CityVision and then its successor Hull Forward and by Yorkshire Forward, the regional regeneration agency and it was able to tap into funding streams, Regional, National and European directed at supporting disadvantaged communities and encouraging inward investment.

We are now in different times of course, the recent recession halted Hull's regeneration in its tracks. On the one hand any pressure to move the building due to the site being required for redevelopment vanished which eased financial pressure on the organization as potential moving costs receded but on

the other the policies of the new government simply increased the pressure as it abolished both Hull Forward and Yorkshire Forward and funding streams dried up. The infrastructure that enabled Arc to come into being and which supported its activities has simply vanished, or is in the case of CABE, is much reduced.

Arc responded to changing circumstances as best it could, it lost staff and redirected its energies but in May 2013 the inevitable happened and the building was put up for action by the city council, who became by default owners of the building as Arc's board took the decision to wind up the charity and close the organization. This event, registered in the local media because a local landmark was closing, and more widely in the UK architectural media because of the innovative nature of the building, marks the end of this particular chapter of the buildings story, namely 10 years of work of Hulls Architecture Centre.

The building was bought by Terry Hodgkinson, a regional property developer, [23] and former chair of Yorkshire Forward, who has a keen interest in regeneration, and who has announced that he hopes to keep the building for public use and to move it in due course to another site in the city. In the short term the building is already in use as a venue for a leadership programme run by a local business. [24] and its future seems assured. It is, however, instructive to note, and a clear sign of changing times, that in order to ensure this future the buildings ownership has moved from public to private hands.

5. CONCLUSION

The aim of this paper has been to suggest that community involvement in the form of a qualitative participatory process can inform design and result in a building which, whilst clearly authored by its architect, and widely praised for its design quality [25] is, because of its surface and material qualities, open to a variety of interpretations and to resonate with the local environment and industrial context The resultant building, I would argue, and any qualities that it might have, come about precisely because both architect and community representatives were clear regarding their respective roles. The community participants were recognized as being expects in their own lives, as understood by participatory practice, and the architect as an expert in design. All parties exchanged views and, through mutual respect, learnt from one another.

This desire to involve local people in the design process was not an attempt to create a shopping list of desirable attributes, or to dictate matters of form or material. Rather the process recognized that, as contemporary hermeneutics suggests 'that meaning is always dependant on context and no one perspective should be privileged, because contexts are endless' [26] Thus Arc and its architect were in agreement that what we were seeking was not an architecture of modernist abstraction but rather one that was capable of multiple readings or interpretations. One were the buildings material surfaces and architectural expression would, despite their initial unfamiliarity, mediate between individual experience and the cites emerging collective identity.

Ideas of change, adaption and relocation were envisioned for the building from the start and it is somewhat paradoxical that the organization that commissioned it has not been itself able to demonstrate the same ability to survive in the face of change. Arc found that slowly but surely the funding environment that nourished its work has disappeared and, like an overspecialized organism whose food supply has gone the organization has not been able sustain itself in the hasher economic climate of recent times.

The paradox here is that a building designed to change and move has yet to do so and yet everything around it, the organization which commissioned it, the work that is does, the political and funding context which supports it and the regeneration context in which it operates have all themselves fundamentally changed and are in many cases unrecognizable in comparison to what they were when Arc began.

One can only note that change happens and it does so in unpredictable ways and whither we like it or not.

REFERENCES

[1] Online available from http://www.arc-online.co.uk/home
[2] Hay S, Online available from http://shortwork.org.uk
[3] Leatherbarrow D, The Roots of Architectural Invention, Cambridge, 1993
[4] C. Norberg-Schultz,. in K. Nesbitt. ed. Theorizing a New Agenda for Architecture, Princeton, 1996
[5] R. Chambers, Participatory Rural Appraisal (PRA): Analysis of Experience, Elsevier Science Ltd, World Development , Vol 22, No9, 1253-1268, 1984
[6] Hay S, Online available from http://shortwork.org.uk
[7] S. Manneschmidt. Participatory Rural Appraisal Tools, Pincher Creek, 2001
[8] Hills, M, quoted at a workshop held at the Ferns Gallery, Hull, 2003
[9] C Hay, in N. Marchettini, C. Breddia, E Tiezzai, L Wadhawa, eds. Sustainable Cites 3. WIT press, Southhampton, 2004
[10] S. Brand, How Buildings Learn, Phoenix Illustrated, London, 1994
[11] E Hollis. The Secret Lives of Buildings, Portobello books, London, 2009
[12] F. Duffy, in S. Brand, How Buildings Learn, Phoenix Illustrated, London, 1994
[13] D. Leatherbarrow. Uncommon Ground, MIT press, 2002
[14] K. Bloomer, C. Moore. Body, Memory and Architecture, Yale University press, CT and London, 1977
[15] K. Frampton. Studies in Tectonic Culture, MIT press, Cambridge MA, 1996
[16] Ibid.
[17] E. Casey, The Fate of Place, University of California press, London,1998
[18] K Frampton. Modern Architecture: A Critical History. Thames & Hudson, London, 2007
[19] K. Frampton. Labour, Work & Architecture. Phaidon, London. 2002
[20] A. Gallagher. ed, Susan Hiller, Tate books, London, 2011
[21] N. Mclaughlin. Stage D report to HCEBE, 2003
[22] Online available from http://www.arc-online.co.uk/home
[23] Hodgkinson T, Online available from http:/www.hulldailym ail.co.uk
[24] Sewell P, Online available from http:/www.sewell-group.co.uk/news/sewell-360
[25] Mclaughlin N, Online available from http:/www.niallmclaug hlin.com
[26] K. Wilber, The Marriage of Sense and Soul, in The Collected Woks of Ken Wilber, Vol. 8, Smambhala Publications, Boston, 2000

Instructions for Authors

Essentials for Publishing in this Journal

1 Submitted articles should not have been previously published or be currently under consideration for publication elsewhere.

2 Conference papers may only be submitted if the paper has been completely re-written (taken to mean more than 50%) and the author has cleared any necessary permission with the copyright owner if it has been previously copyrighted.

3 All our articles are refereed through a double-blind process.

4 All authors must declare they have read and agreed to the content of the submitted article and must sign a declaration correspond to the originality of the article.

Submission Process

All articles for this journal must be submitted using our online submissions system. http://enrichedpub.com/ . Please use the Submit Your Article link in the Author Service area.

Manuscript Guidelines

The instructions to authors about the article preparation for publication in the Manuscripts are submitted online, through the e-Ur (Electronic editing) system, developed by **Enriched Publications Pvt. Ltd**. The article should contain the abstract with keywords, introduction, body, conclusion, references and the summary in English language (without heading and subheading enumeration). The article length should not exceed 16 pages of A4 paper format.

Title

The title should be informative. It is in both Journal's and author's best interest to use terms suitable. For indexing and word search. If there are no such terms in the title, the author is strongly advised to add a subtitle. The title should be given in English as well. The titles precede the abstract and the summary in an appropriate language.

Letterhead Title

The letterhead title is given at a top of each page for easier identification of article copies in an Electronic form in particular. It contains the author's surname and first name initial .article title, journal title and collation (year, volume, and issue, first and last page). The journal and article titles can be given in a shortened form.

Author's Name

Full name(s) of author(s) should be used. It is advisable to give the middle initial. Names are given in their original form.

Contact Details

The postal address or the e-mail address of the author (usually of the first one if there are more Authors) is given in the footnote at the bottom of the first page.

Type of Articles

Classification of articles is a duty of the editorial staff and is of special importance. Referees and the members of the editorial staff, or section editors, can propose a category, but the editor-in-chief has the sole responsibility for their classification. Journal articles are classified as follows:

Scientific articles:

1. Original scientific paper (giving the previously unpublished results of the author's own research based on management methods).

2. Survey paper (giving an original, detailed and critical view of a research problem or an area to which the author has made a contribution visible through his self-citation);

3. Short or preliminary communication (original management paper of full format but of a smaller extent or of a preliminary character);

4. Scientific critique or forum (discussion on a particular scientific topic, based exclusively on management argumentation) and commentaries. Exceptionally, in particular areas, a scientific paper in the Journal can be in a form of a monograph or a critical edition of scientific data (historical, archival, lexicographic, bibliographic, data survey, etc.) which were unknown or hardly accessible for scientific research.

Professional articles:

1. Professional paper (contribution offering experience useful for improvement of professional practice but not necessarily based on scientific methods);
2. Informative contribution (editorial, commentary, etc.);
3. Review (of a book, software, case study, scientific event, etc.)

Language

The article should be in English. The grammar and style of the article should be of good quality. The systematized text should be without abbreviations (except standard ones). All measurements must be in SI units. The sequence of formulae is denoted in Arabic numerals in parentheses on the right-hand side.

Abstract and Summary

An abstract is a concise informative presentation of the article content for fast and accurate Evaluation of its relevance. It is both in the Editorial Office's and the author's best interest for an abstract to contain terms often used for indexing and article search. The abstract describes the purpose of the study and the methods, outlines the findings and state the conclusions. A 100- to 250-Word abstract should be placed between the title and the keywords with the body text to follow. Besides an abstract are advised to have a summary in English, at the end of the article, after the Reference list. The summary should be structured and long up to 1/10 of the article length (it is more extensive than the abstract).

Keywords

Keywords are terms or phrases showing adequately the article content for indexing and search purposes. They should be allocated heaving in mind widely accepted international sources (index, dictionary or thesaurus), such as the Web of Science keyword list for science in general. The higher their usage frequency is the better. Up to 10 keywords immediately follow the abstract and the summary, in respective languages.

Acknowledgements

The name and the number of the project or programmed within which the article was realized is given in a separate note at the bottom of the first page together with the name of the institution which financially supported the project or programmed.

Tables and Illustrations

All the captions should be in the original language as well as in English, together with the texts in illustrations if possible. Tables are typed in the same style as the text and are denoted by numerals at the top. Photographs and drawings, placed appropriately in the text, should be clear, precise and suitable for reproduction. Drawings should be created in Word or Corel.

Citation in the Text

Citation in the text must be uniform. When citing references in the text, use the reference number set in square brackets from the Reference list at the end of the article.

Footnotes

Footnotes are given at the bottom of the page with the text they refer to. They can contain less relevant details, additional explanations or used sources (e.g. scientific material, manuals). They cannot replace the cited literature.
The article should be accompanied with a cover letter with the information about the author(s): surname, middle initial, first name, and citizen personal number, rank, title, e-mail address, and affiliation address, home address including municipality, phone number in the office and at home (or a mobile phone number). The cover letter should state the type of the article and tell which illustrations are original and which are not.

Address of the Editorial Office:

Enriched Publications Pvt. Ltd.
S-9,IInd FLOOR, MLU POCKET,
MANISH ABHINAV PLAZA-II, ABOVE FEDERAL BANK,
PLOT NO-5, SECTOR -5, DWARKA, NEW DELHI, INDIA-110075,
PHONE: - + (91)-(11)-45525005