# Beyond the Minimum:
## A Durable Emergency Shelter

by
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‘I hereby declare that I am the sole author of this thesis. This is a true copy of the thesis, including any required final revisions, as accepted by my examiners.

I understand that my thesis may be made electronically available to the public.’

# Abstract

The number of states requiring humanitarian assistance after a disaster has doubled every decade since 1960. Extreme weather like flooding and violent storms associated with climate change are predicted to continue to increase with intensity and in frequency in the future. Traditionally, emergency shelters have been given in the form of two options: the tent or the tarp. While both do a great job at addressing immediate shelter needs, they are not durable enough habitations to provide adequate transitional shelter for the time period between six months and two years. Most emergency shelters provided by humanitarian agencies fail before six months.

This thesis will investigate the development of an emergency shelter solution that improves upon the current options for affected regions following a disaster within warm climates. The thesis proposes that by employing more robust materials for emergency shelters the life expectancy can be extended to meet the required needs.

Several materials and designs were explored, tested, and evaluated as plausible shelter solutions to accomplish this task. Design shapes including Roman and Gothic arches were tested with smoke simulations, wind load calculations, and continuous frame loading. The most successful design tested, the Roman arch, was then contrasted and compared to currently used disaster relief shelters for durability and cost. Thesis findings indicate that there is potential for economical and durable emergency shelter solutions. Further research on this topic will increase the number of shelter options available to humanitarian organizations in order to help both emergency and transitional shelter roles simultaneously.

# Acknowledgements


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Lastly, I would like to thank all of my family, friends, and other positive people in my life for all of your time, support, and encouragement. Without friends and family like you this thesis would not have been possible.

# Dedication

This thesis is dedicated to all of the people that have helped me in my educational journey, thank-you for believing in me.

# Contents

## CONSIDERATION



## ELEMENTS



## DEVELOPMENT



## DÉNOUEMENT

# List of Figures

## INTRODUCTION



## SITUATION



## APPROACHES



## CONSIDERATION



## ELEMENTS



## DEVELOPMENT



## DÉNOUEMENT

# List of Images

## COVER/BACK COVER

Untitled Image http://digitaljournal.com/img/3/6/0/2/1/4/i/6/3/9/o/800px-Tent_city_in_Port-au-Prince_2010-01-21.jpg

## PROLOGUE

Untitled Image http://clikhear.palmbeachpost.com/wp-content/uploads/2010/08/pakeyes.jpg

## INTRODUCTION

Image A01 http://zerowasteland.files.wordpress.com/2011/09/tondo-slum.jpg

## SITUATION

Situation Spread: http://www.photographium.com/tent-village-thessalonike-greece-1917
http://www.photographium.com/sites/default/files/after_the_great_fire_in_saloniki._thessalonike_greece._1917.jpg
Image A02 http://cf1.8tracks.us/mix_covers/000/648/365/81758.max1024.jpg
Image A03 http://www.bradshawfoundation.com/india/central_india/bhimbetka/26b.jpg Photographed by Dr. Jean Clottes
Image A04 http://209.82.14.226/history/inventions/ Photographed by Andrew Gregorovich
Image A05 Fol. 15 v. Woodcut by Jean Goujon "Illustration of the Primidoral hut." 1547. (Evers, Bernd, Architectural Theory. Taschen. Koln, Germany. 2006. pg 119.)
Image A06 http://www.tarch.com/sito_02/immagini/forum/sdegno/grandi/01.jpg
Image A07 http://www.tu-cottbus.de/theoriederarchitektur/wolke/eng/Subjects/072/Blais/figure-3.jpg
Image A08 http://upload.wikimedia.org/wikipedia/commons/d/de/Membrane_Roof_and_Tensile_Lattice_Shell_of_Shukhov_Rotunda_1895.jpg
Image A09 http://3.bp.blogspot.com/_VUXdeaeI4xk/SPM_JqDfCHI/AAAAAAAADOQ/n47OFDUvj6w/s400/IMG_8169.JPG
Image A10 http://hcap.artstor.org/collect/cic-hcap/index/assoc/p1789.dir/Student%20Center.jpg
Image A11 http://farm4.staticflickr.com/3237/2826489568_aeaed178f5_o.jpg Photographed by Peter Gasston
Image A12 http://3.bp.blogspot.com/-PJmZ4RKShn4/Tm2Mz5yDizI/AAAAAAAAPxA/m7NgY1RLGGk/s1600/World+Most+Expensive+Hotel+-+Burj+Al+Arab+2.jpg
Image A13 http://www.pro.rcip-chin.gc.ca/sgc-cms/dvp-pvd/db_images/01-00004.jpg
Image A14 http://www.docstoc.com/docs/81409867/Black-tent-the-bedouin-tent
Image A15 http://numod.hotglue.me/Yurts.head.130105868772
Image A16 http://www.arch.mcgill.ca/prof/sijpkes/D+C-winter-2005/pavillions_tensile/014_p19___kuchi_tents_near_qalainau_afghanistan.jpeg
Image A17 http://images2.sina.com/english/life/p/2010/1014/U99P200T1D343525F14DT20101014023931.jpg Photographed by Sisi Tang, Associated Press
Image A18 http://intercontinentalcry.org/wp-content/uploads/hebron-bedouin-village.jpg Photographed by Haytham Othman, MaanImages
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Image A20 http://www.amazon.com/gp/product/images/B0009PUTIE/ref=dp_otherviews_z_0?ie=UTF8&s=outdoor-recreation&img=0
Image A21 http://www.amazon.com/Tents-Accessories-Camping-Hiking/b/ref=amb_link_353746022_3?ie=UTF8&node=1258595011&pf_rd_m=ATVPDKIKX0DER&pf_rd_s=center-7-0&pf_rd_r=00TRPQFDA9BADC4V2CXC&pf_rd_t=101&pf_rd_p=1374389702&pf_rd_i=3375251
Image A22 http://www.besportier.com/images/2m-dome-tent1.jpg
Image A23 http://kaufmann-mercantile.com/images/canvas-fabric.jpg
Image A24 http://www.cas.muohio.edu/~meicenrd/anatomy/Ch6_Supportive/fabric_ripstop_350.jpg
Image A25 https://web.tradekorea.com/upload_file2/product/735/P00289735/cbe9caa6_27b80af2_42ab_4ea9_98ec_77c025c13fe9.jpg
Image A26 created by Jason Child with images from these websites:
http://www.best-campingtents.com/wp-content/uploads/2011/12/redcanyon_tent.png
http://www.transportation-expert.com/b2b/pics/Fiberglass_Tent_Pole.jpg
http://www.amazonoutdoors.com.au/e2Shop/uploads/330/Supex%2010x%20Extension%20Poles.jpg
http://www.mcnett-outdoor.com/uploads/Images/tactical/TctRepGuide/TctRgTentsS1P3.jpg
http://www.scouttech.com/ProdImages/abs_tent_stakes.jpg
http://www.adventuretravelkit.co.uk/images/product/213df8e04b975082d94a29326e397b9d.jpg
http://adventurefriends.com.au/product_images/y/635/2_inches%29___88159_zoom___43499_zoom.jpg

## APPROACHES

Perspectives Spread: http://www.southcom.mil/media/pictures/Main/633995203029843750.jpg
Image B01 http://www.foundinternational.com/wp-content/uploads/2011/11/found-small-tool-bag-tools1.jpg
Image B02 http://ingaza.files.wordpress.com/2009/02/48.jpg
Image B03 http://www.chfinternational.org/files/images466/ti_Earthquake_Response_March_4_2010_009small.jpg
Image B04 http://www.nicolaslefevre.com/5/photos_medium/NL_13.jpg Photographed by Nicolas Lefevre
Image B05 http://www.sheltercentre.org/sites/default/files/14_-_tsg_presentation_sm11a.pdf page 5
Image B06 http://practicalaction.org/docs/ia3/building-back-better-lyons-schilderman.pdf (pg 150)
Image B07 http://blog.advanceaid.org/wp-content/uploads/2011/09/WV_Dadaab_1.jpg
Image B08 http://2.bp.blogspot.com/-UdGQUMPmxM0/TgYlRwgRfzI/AAAAAAAAAG0/sLbRVzL7f4Y/s1600/blue+tarp.jpg
Image B09 https://web.tradekorea.com/upload_file2/product/400/P00233400/cbe9caa5_03b71657_9fdc_45e1_96bc_5125c4dacd18.jpg
Image B10 http://crs-blog.org/wp-content/uploads/2010/03/HAI2010033479.jpg Photographed by David Snyder, Catholic Relief Services
Image B11 http://josephashmore.org/publications/tents.pdf (pg 26-25) Drawn by Joseph Ashmore
Image B12 http://farm5.staticflickr.com/4035/4399017142_b8ea2cc7d5_o.jpg United Nations Photograph
Image B13 http://desmond.yfrog.com/Himg620/scaled.php?tn=0&server=620&filename=g6zmd.jpg&xsize=640&ysize=640
Image B14 http://i01.i.aliimg.com/img/pb/822/691/386/386691822_486.jpg
Image B15 http://msnbcmedia.msn.com/j/MSNBC/Components/Photo/2010/January/100126/pb-sy-hdview-100127.photoblog900.jpg Photographed by Andr Chung
Image B16 http://www.instablogsimages.com/images/2010/03/21/haiti-tent-cities_hPEzs_16105.jpg
Image B17 Ashmore, Joseph, "Shelter Solutions Review - Haiti." May 2010. Pg 12.
Image B18 http://www.mdmshelters.com/images/products/un_tent/un_tent_g1.jpg
Image B19 http://www.homefun.com.cn/uppic/20104241656101722 4.jpg
Image B20 http://www.westernwalltents.com/catalog/images/Relief%20Tent%20Dome.jpg
Image B21 http://www.rddusa.com/images/products/military%20tents/military-tent-m1945-command-post-US-400.jpg.jpg
Image B22 http://www.nuggetbuy.com/image/cache/data/dis-500x500.jpg
Image B23 http://www.rddusa.com/images/products/military%20tents/gp-medium.jpg
Image B24 http://www.unicef.org/philippines/3Q9R3339_inside.jpg Photographed by J. Maitem, UNICEF
Image B25 http://jessieboylan.files.wordpress.com/2009/06/jabaliya_tents_02.jpg?w=720
Image B26 http://repeatingislands.files.wordpress.com/2010/11/haiti2.jpg?w=500&h=333
Image B27 http://jameshowell.files.wordpress.com/2010/10/busted-zipper1.jpg
Image B28 http://www.au104.org/Photo3/images46-50/104Sigs_46-11.jpg
Image B29 http://www.bz1-img.com/images_customers/05/73/9323983_77263_full.jpg
Image B30 http://www.newsudangeneration.org/images/Failed%20tent.JPG
Image B31 http://www.flickr.com/photos/minustah/5812922871/sizes/o/in/set-72157626793671661/
Image B32 http://i234.photobucket.com/albums/ee45/johnnie_056/Alternative%20Methods%20build/WATER2.jpg
Image B33 http://jamesgordonmd.com/healingourselves/wp-content/uploads/2011/01/cmbm-workshop-petionville-1.11.11-212.jpg
Image B34 http://3.bp.blogspot.com/-5S86MX7stig/TxhoeT4Ht8I/AAAAAAAAA4A/FBuAc8etE8I/s1600/20110603_GUY_R93_3950.JPG
Image B35 Trujillo, Catherine, "Audit of USAID's Efforts to Provide Shelter in Haiti." Office of the Inspector General. Audit Report NO. 1-521-11-003-P. San Salvador, El Salvador. April 19, 2011. Pg 6.
Image B36 http://jamesgordonmd.com/healingourselves/wp-content/uploads/2011/01/Champs-de-Mars-tent-camp-PaP-Haiti-12-10.jpg
Image B37 http://lh4.ggpht.com/_XbJJ801AbSA/SajZvMNz6bI/AAAAAAAADnM/y3FSOOMr0ns/s400/noorani%20mohalla%201.jpg

Image B38 http://ochaonline.un.org/Portals/11/A%20family%20in%20a%20makeshift%20hut%20made%20of%20tarpaulin%20sheets%20in%20front%20of%20their%20destroyed%20house%20in%20Tarlay%20Sub-Township%20IRIN%20Myanmar.jpg
Image B39 http://crs.org/haiti/img/HAI2010034652.jpg
Image B40 http://www.cwmission.org/images/stories/features_2010/elephants.jpg

## CONSIDERATION

Consideration Spread http://garyschapman.com/gallery/large/20080122_kenya_207-Edit.jpg Photgraphed by Gary Schapman
Image C01 http://www.flickr.com/photos/minustah/7184924133/sizes/o/in/photostream/ Photgraphed by Marco Dormino, United Nations Stabilization Mission in Haiti
Image C02 http://2.bp.blogspot.com/-fqSeEPbttdk/TeU47CBSNBI/AAAAAAAAAgw/w7sJsY_KteY/s1600/This+is+the+Mayor+of+Delmas+in+Action-+Destroying+the+Shelter+of+IDPs+during+rainy+season.jpg Photgraphed by Beverly Bell
Image C03 http://nakedchiefs.files.wordpress.com/2012/05/idp-camp.jpg Photgraphed by Erick Christian, Ahonounou/APA
Image C04 http://4.bp.blogspot.com/_j82KWR_Gj8g/TFKeamZVaSI/AAAAAAAAANo/XFKr1rgvutI/s1600/Sahara_Sudanese_Rebel_Group.jpg
Image C05 http://4.bp.blogspot.com/-V3AjnGvw9a4/TeU4-v_PV0I/AAAAAAAAAg8/5zFipPxUxkE/s1600/5759442234_d4e381e2be_o.jpg
Image C06 http://www.theatlantic.com/infocus/2011/04/ivory-coasts-leader-under-siege/100040/ Photgraphed by Thierry Gouegnon, Reuters
Image C07 http://a5.sphotos.ak.fbcdn.net/hphotos-ak-snc7/417301_364346463586231_689718170_n.jpg
Image C08 http://www.usicd.org/images/photo/WHO%20report%20one%20million.jpg
Image C09 http://inapcache.boston.com/universal/site_graphics/blogs/bigpicture/africahorn-drought_072211/bp12.jpg Photgraphed by Rebecca Blackwell, Associated Press
Image C10 http://images.huffingtonpost.com/2010-11-09-canaan.jpg
Image C11 http://ootp.files.wordpress.com/2010/01/water_100116.png?w=600&h=431
Image C12 http://worldrelief.org/view.image?Id=2274
Image C13 Ashmore, Joseph, Tents: A guide to the use and logistics of family tents in humanitarian relief. United Nations Publication. pg.9
Image C14 Ashmore, Joseph, Tents: A guide to the use and logistics of family tents in humanitarian relief. United Nations Publication. pg.9
Image C15 http://nikischwabe.files.wordpress.com/2011/04/self-settled-camp-dynamics.jpg illustrated by Niki Schwabe
Image C16 http://nikischwabe.files.wordpress.com/2011/03/refugee-camp-design-2-a.jpg
Image C17 by author Jason Child
Image C18 http://www.newslinemagazine.com/wp-content/gallery/idp-camps-pakistan/idp-camps.gif
Image C19 http://www.somaliareport.com/images_large/Mogadishu_IDP_Camp.jpg
Image C20 http://tachatrendz.com/theblog/wp-content/uploads/2011/01/haiti-earthquake-homeless2.jpg

## ELEMENTS

Elements Spread http://blogs.cv.vic.gov.au/news/files/2011/07/textile-factory-2.jpg
Image D01 http://www.preferredpest.com/images/termites-dwg.jpg
Image D02 http://www.cabinetmagazine.org/issues/25/termite03.jpg
Image D03 http://www.jaiom18.com/wp-content/uploads/2010/12/Rust.jpg
Image D04 http://lh4.ggpht.com/-ns2P_P2z2OE/TtpewNxVpSI/AAAAAAAAjgA/b7IOWlGaDVg/IMG_3170.jpg
Image D05 http://www.camping-tents.biz/tent_parts_accessories.jpg
Image D06 http://www.towsure.com/images/products/8420/detail/vango-airbeam-infinity-800-8-person-tent-inflatable.jpg
Image D07 https://www.canvastentshop.co.uk/images/content/large/Canvas-Ridge-Tent-Brown.png
Image D08 http://www.armynnavy.com/catalog/catalog/images/green-canvas-patrol-tent-fly-sheet.png
Image D09 http://msnbcmedia1.msn.com/j/MSNBC/Components/Photo/_new/100319-haiti-rain-hmed12p.grid-6x2.jpg
Image D10 http://franciskagolo.files.wordpress.com/2011/12/poor-sanitation-in-slums.jpg
Image D11 http://ic2.pbase.com/o4/93/329493/1/90809667.POrKTpMf.VietnamDec07731.jpg Photographed by Brian J. McMorrow
Image D12 http://www.topallets.com/images/pallet.jpg
Image D13 http://www.vrr-aviation.com/media/images/2008813_847773886_large.jp
Image D14 http://horizoninbusiness.com/sitebuildercontent/sitebuilderpictures/ld3-2.jpg
Image D15 http://www.inter-con.us/images/20dry.jpg
Image D16 http://ootp.files.wordpress.com/2011/05/jbb-cry-to-shut-down-in-may_110421-a-mp618-262.png
Image D17 http://www.europarl.europa.eu/data/resources/library/images/20070607PHT07623/20070607PHT07623_original.jpg
Image D18 http://haitiearthquakephotos.com/earthquake-photos/d/2793-3/Aerodome+de+Jacmel

## DEVELOPMENT

Development Spread image created by Jason Child
Image E01 http://www.trust.org/resize_image?path=/dotAsset/fd6d299d-f1a6-4d2d-a396-87240dd96b88.jpg&w=649
Image E02 by Jason Child
Image E03 by Jason Child
Image E04 by Jason Child
Image E05 by Jason Child
Image E06 by Jason Child
Image E07 by Jason Child
Image E08 by Jason Child
Image E09 by Jason Child
Image E10 by Jason Child
Image E11 by Jason Child
Image E12 by Jason Child
Image E13 by Jason Child
Image E14 by Jason Child
Image E15 http://www.bowsports.com/beginners_stringing_bow.gif
Image E16 by Jason Child
Image E17 by Jason Child
Image E18 by Jason Child
Image E19 by Jason Child
Image E20 by Jason Child
Image E21 by Jason Child
Image E22 by Jason Child
Image E23 by Jason Child
Image E24 by Jason Child
Image E25 by Jason Child
Image E26 by Jason Child
Image E27 by Jason Child
Image E28 by Jason Child
Image E29 by Jason Child
Image E30 by Jason Child
Image E31 by Jason Child
Image E32 by Jason Child
Image E33 by Jason Child
Image E34 by Jason Child
Image E35 by Jason Child
Image E36 by Jason Child
Image E37 by Jason Child
Image E38 by Jason Child
Image E39 by Jason Child
Image E40 by Jason Child
Image E41 by Jason Child
Image E42 by Jason Child
Image E43 by Jason Child
Image E44 by Jason Child
Image E45 by Jason Child

Image E46 by Jason Child
Image E47 by Jason Child
Image E48 by Jason Child
Image E49 by Jason Child
Image E50 by Jason Child
Image E51 by Jason Child
Image E52 by Jason Child
Image E53 by Jason Child
Image E54 by Jason Child
Image E55 by Jason Child
Image E56 by Jason Child
Image E57 by Jason Child
Image E58 by Jason Child
Image E59 by Jason Child
Image E60 by Jason Child
Image E61 by Jason Child

## DÉNOUEMENT

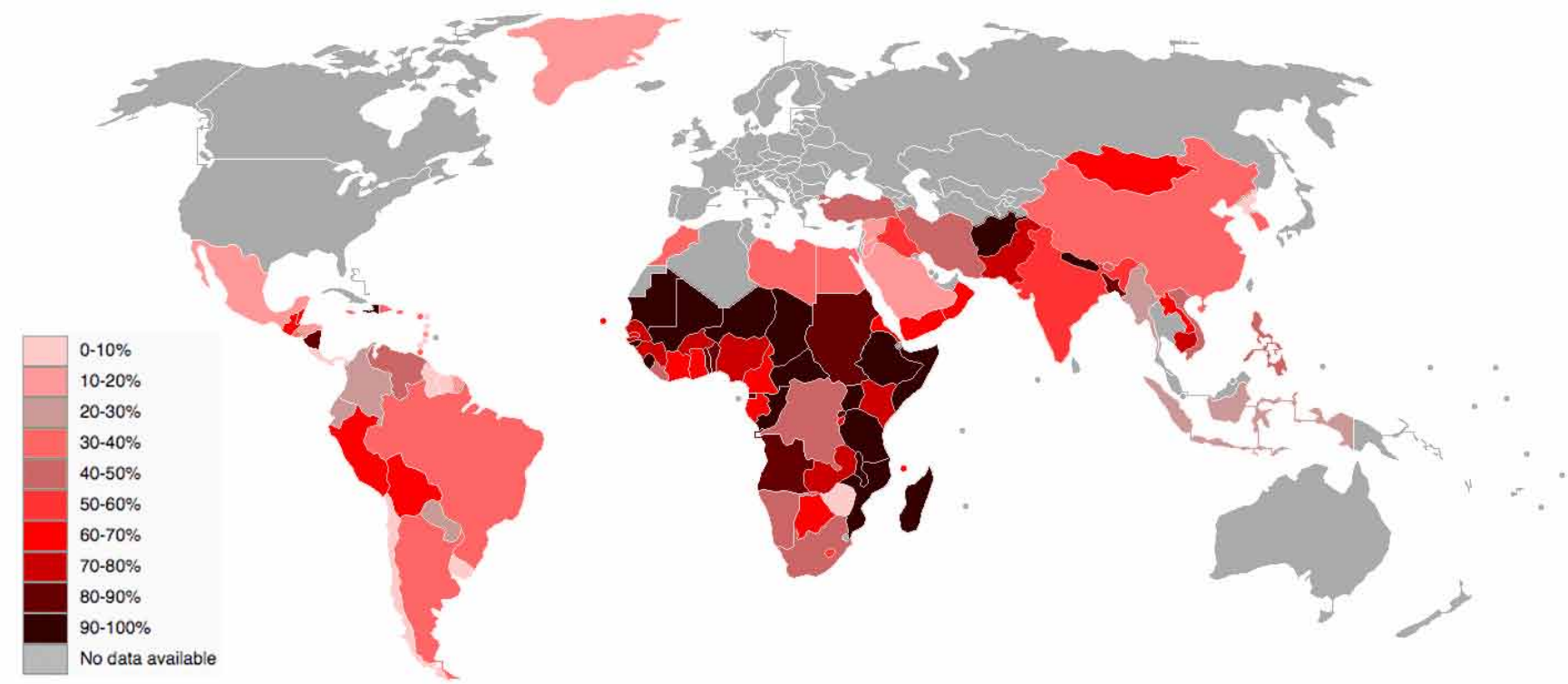
Image F01 http://talesfromethehood.files.wordpress.com/2010/02/myanmar1.jpg
Image F02 screenshot from: http://www.youtube.com/watch?v=AT_gCXgQ7xE
Image F03 http://www.shelterbox.org/uploads/images/Tent.jpg
Image F04 http://ecx.images-amazon.com/images/I/41ea9t2jj9L.jpg
Image F05 Image E74 http://i00.i.aliimg.com/photo/v0/377332944/UN_light_weight_emergency_tent.jpg
Image F06 by Jason Child
Image F07 http://i00.i.aliimg.com/img/pb/324/006/236/1266994906901_hz_fileserver1_398039.jpg
Image F08 http://i00.i.aliimg.com/img/pb/303/395/481/481395303_822.jpg
Image F09 by Jason Child
Image F10 by Jason Child
Image F11 by Jason Child with data from: http://cnx.org/content/m38482/latest/Picture%205.jpg
Image F12 by Jason Child with data from: http://www.worldriskreport.com/uploads/media/WRB_2012_WKwri_RGB_WRI2.jpg
Image F13 by Jason Child
Image F14 by Jason Child
Image F15 by Jason Child
Image F16 by Jason Child

## APPENDIX

Image X01 by Jason Child
Image X02 by Jason Child
Image X03 by Jason Child
Image X04 by Jason Child
Image X05 by Jason Child
Image X06 by Jason Child
Image X07 by Jason Child
Image X08 by Jason Child
Image X09 by Jason Child
Image X10 by Jason Child
Image X11 by Jason Child
Image X12 by Jason Child
Image X13 by Jason Child
Image X14 by Jason Child
Image X15 by Jason Child
Image X16 by Jason Child
Image X17 by Jason Child
Image X18 by Jason Child
Image X19 by Jason Child

"We have the necessary skills and expertise to help people. We cannot ignore this. It is our obligation." Shigeru Ban, Architect

# BEYOND THE MINIMUM




Percentage of Urban Population Living in Slums

Fig. 1.01

# Natural Disasters: A Global Analysis

Disaster: A serious disruption of the functioning of a community or a society causing widespread human, material, economic or environmental losses which exceed the ability of the affected community or society to cope using its own resources.[1]

Fig. 1.01 (opposite)
The United Nations agency UN-HABITAT defines slum as a run-down area of a city characterized by substandard housing, squalor, and lacking in tenure security. UN-HABITAT estimates that more than one billion people are living in slums. That is 1 out of every 3 city dwellers globally and one seventh of the Earth's total population[2].

Over the last several decades, scientists have been documenting an increase in the number of natural disasters that occur each year.[3] Studies have shown that the increase in hydrological disasters, including hurricanes, droughts, and flooding, could be attributed to global warming.[4] However, there is currently insufficient data to define global warming as the main cause of a worldwide escalation in natural disasters.[5] Major natural disasters often occur within developing regions of the world that are experiencing significant increases in urbanization.[6]

According to Mark Pelling, (author of *Natural Disasters and Development: In a Globalizing World*) the number of natural disasters that require humanitarian assistance has doubled each decade since 1960.[7] Flooding is about to surpass droughts as the greatest threat to mankind in the upcoming decades. As of 2011, flooding now accounts for 40% of the world's natural disasters. This has affected 400 million people each year for the past two decades. Evidence shows that the occurrence of flood disasters has doubled within the last twenty years.[8] Extreme weather, for example flooding and violent storms (hydrological disasters), associated with climate change are predicted to continue to increase in intensity and frequency in the near future.[9]

(see page 24 for end notes)

Five and a half billion people live in less-developed regions. This accounts for 82% of the world's total population. Of this percentage, 835 million live in 49 of the least-developed nations, and they account for 12% of the world's population. As the world's population increases, the immigrant poor flock toward dense informal settlements (slums), assuming they may have the opportunity to exploit the perceived economic prospects that cities offer. Populations living in slums are almost non-existent in the developed world. The proportion of people living in slums in less-developed regions is 37%. This proportion of the population rises further for the least-developed regions, where 74% of the metropolitan population lives in slums. In the continent of Africa the problem is most pronounced. In some African countries over 90% of the urban population live in slums.[10]

"More than 100,000 people died the year of 2006 in 650 natural disasters that cost the world economies an estimated $210bn. How natural were these disasters?" More than thirty years ago, Ben Wisner, Ken Westgate and Phil O'Keefe, published their research *Taking the Naturalness Out of Natural Disasters* in the journal *Nature*. This research provided the foundation for information that is now widely agreed upon (Tiranti, 1977; Oliver-Smith, 1986; Hewitt, 1997; Lewis, 1999; Mileti et al., 1999; Steinberg, 2000; Wisner et al., 2004). "Nature makes volcanic eruptions, earthquakes, landslides, floods and windstorms, but humans are responsible for the deaths. And the humans most likely to die are the poor and the outcast."[11]


The North-South divide shows itself most clearly in times of disaster. A 6.5 quake located at central California took only 2 lives and injured 40 people. Four days later a quake with a 6.6 magnitude struck Iran killing over 40,000 people. These earthquakes took place in areas of similar population density.[12]

Image A01 (above)
Tondo District, Manila, Philippines.
These homes will not survive a major disaster.

Fig. 1.02 (opposite)
The increasing frequency of global natural disasters.
(Note: OFDA, CRED, and EM-DAT were created to monitor disasters anddisaster frequency)

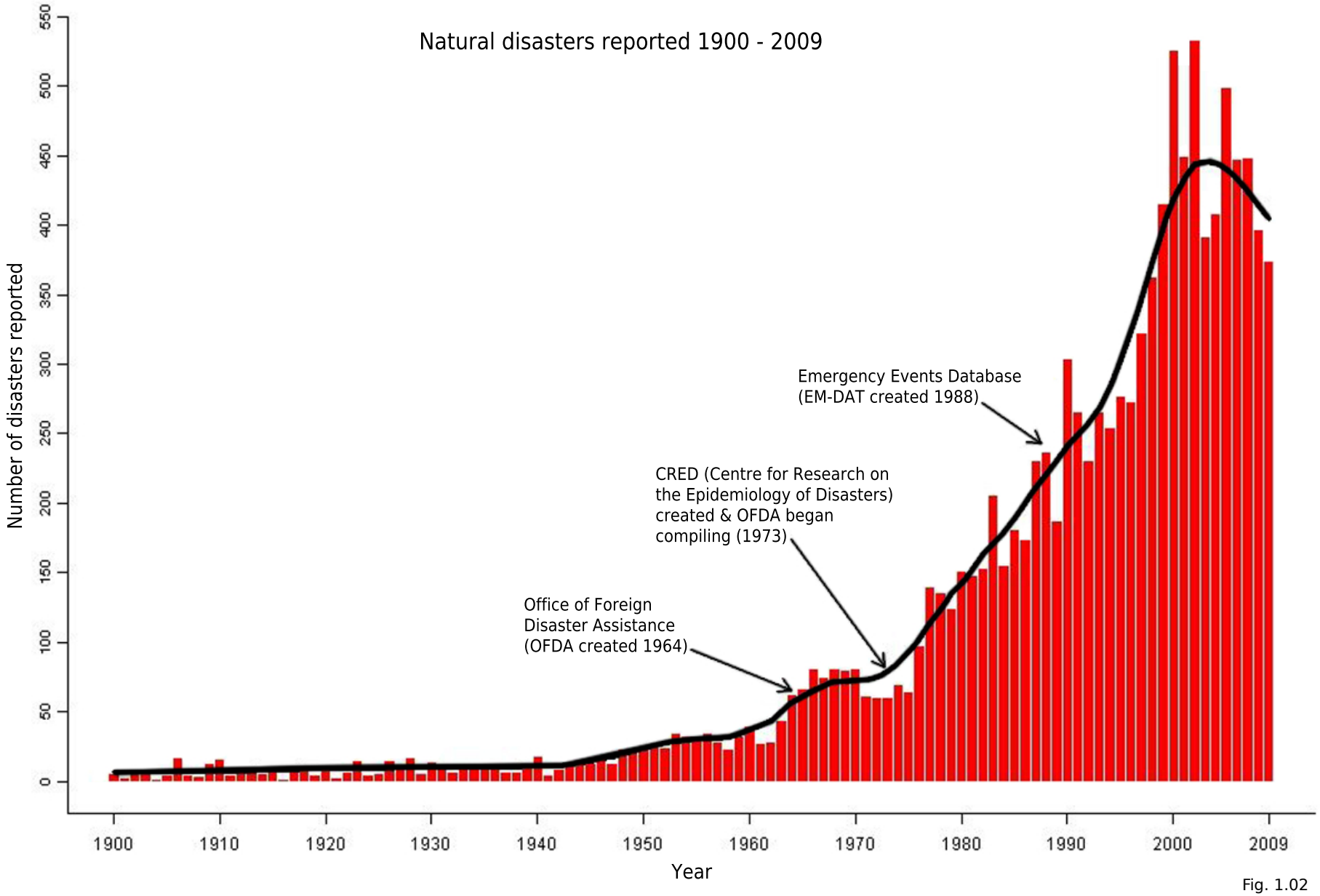

Natural disasters reported 1900 - 2009
Number of disasters reported
0
50
100
150
200
250
300
350
400
450
500
550
1900
1910
1920
1930
1940
1950
1960
1970
1980
1990
2000
2009
Year
Emergency Events Database
(EM-DAT created 1988)
CRED (Centre for Research on
the Epidemiology of Disasters)
created & OFDA began
compiling (1973)
Office of Foreign
Disaster Assistance
(OFDA created 1964)

Fig. 1.02

# SITUATION

# Origin of Aid Organizations and Their Developing Role

"The moral worth of an action does not lie in the effect expected from it, nor in any principle of action which requires to borrow its motive from this expected effect." - Immanuel Kant[1]

**Growth of intergovernmental organizations (IGOs), non-governmental organizations (NGOs) and states since 1900.**

Source: Yearbook of International Organizations 1993/94, Union of International Associations

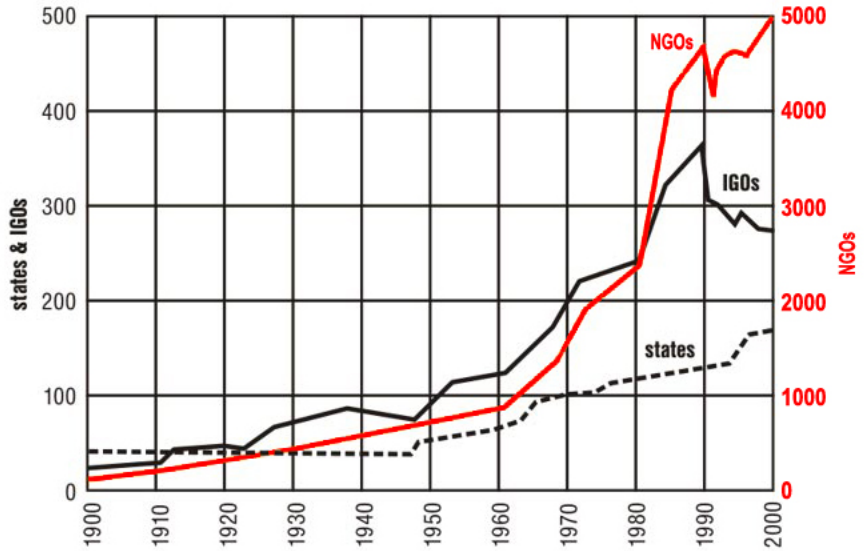



Fig. 1.03

International Committee of the Red Cross is the original credited humanitarian organization, established in 1863 after Henry Dunant published *A Souvenir of Solferino* in 1862. In 1864, some governments adopted the proposals suggested by the initial Geneva Convention. Officials at this convention agreed that wounded soldiers in combat deserved remedial treatment no matter where they pledged allegiance. The original role of the ICRC (International Committee of the Red Cross) was to act as a medical coordinator. By the time First World War began it was apparent that there was a need for neutrality on the battlefield concerning medical attention. ICRC began offering treatment to wounded soldiers of each side.[2]

Before ICRC, the role of humanitarian aid was done by churches or other religious organizations and to some extent various branches of government or monarchies. The UN itself was not formed until after the Second World War in 1945. The main goal of the UN was to keep peace between nations and resolve conflicts. Over the past 65 years, it has expanded into 93 different committees, agencies, programs, and subsidiary bodies.[3]

As of December 2011, the USA alone has 440,040 registered non-profit organizations with NCCS Core Files and IRS Business Master Files, as well as 93,349 private organizations, and 635,924 public charities.[4] Many of these organizations are involved in international

humanitarian work and there are registered duplicates of the same organization located in different states.

During the period from 1990-1995, the citizen sector (non profit, NGOs, social entrepreneurs) grew at a rate three times greater then the combined economies of USA, European Union and Japan. In the year 2000, Ashoka (global network of social innovators) reported that the number of international citizens group was at 27,000 compared to just 6,000 in 1990.[5]

Except for religious institutions, the idea of a non-governmental aid organization is a relatively new concept for humanity. In the span of under 150 hundred years there are presumably hundreds if not thousands of non-government institutions across the globe.

After the great fire of London in 1666, King Charles provided a number of tents to those who lost their homes and the permission to set up dwellings temporarily in open spaces throughout the city.[6]

Shelter was given to the affected population reluctantly by the US Government following the 1906 San Francisco earthquake. Mayor Eugene Schmitz of San Francisco feared that people living in wooden transitional shelters would not want to leave their new homes.[7]

In 1935 the Nansen International Office for Refugees was one of the first to donate shelters to those in need by a non-governmental agency. They constructed villages in Syria and Lebanon for over 40,000 Armenian refugees.[8] This was by far the largest shelter project provided by any non-government agency to date. During the Arab-Israeli War in 1948, refugees fleeing conflict

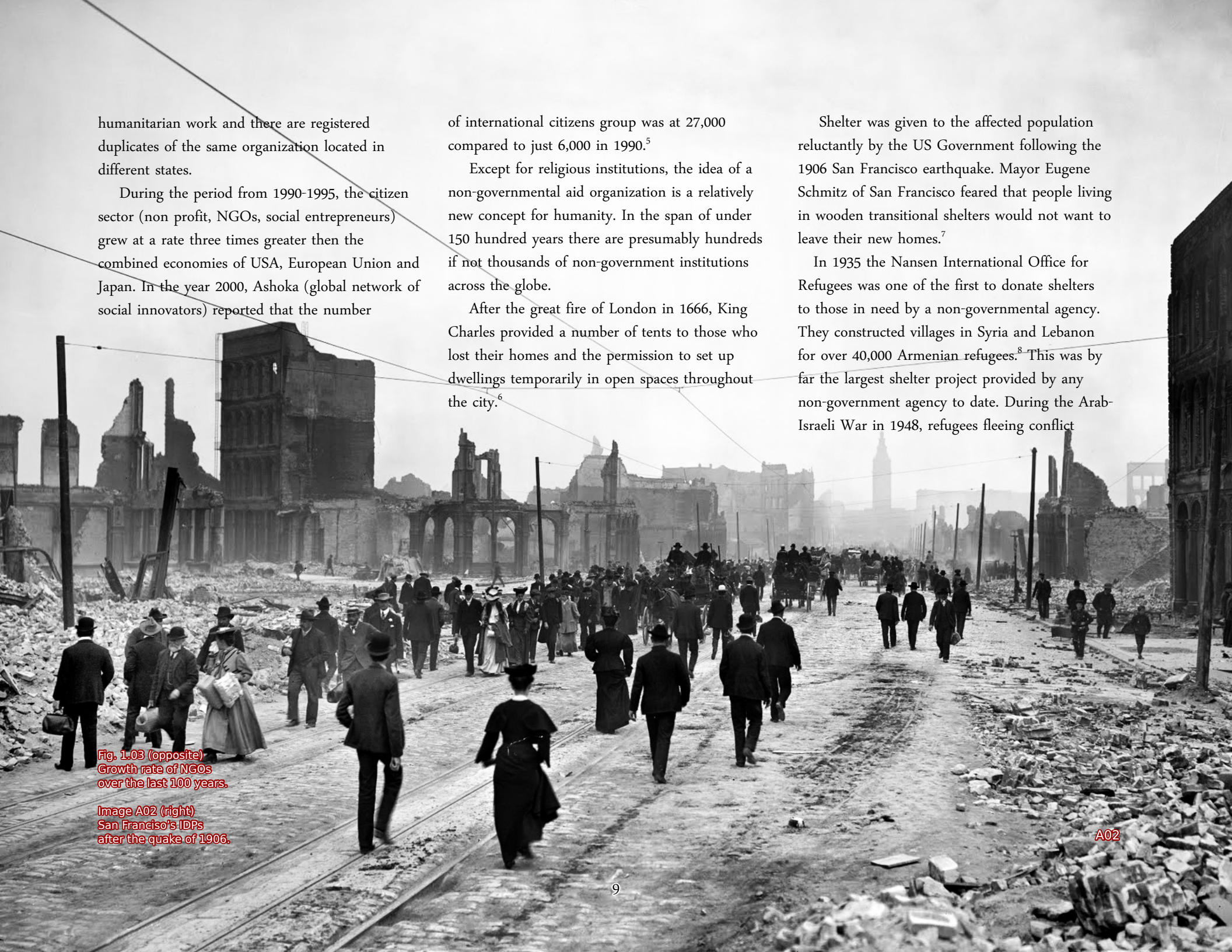


Fig. 1.03 (opposite)
Growth rate of NGOs
over the last 100 years.

Image A02 (right)
San Francisco's IDPs
after the quake of 1906.

A02

were some of the first groups of people to receive temporary emergency shelter by the UN along with other NGO partner organizations.[9] The ICRC started providing shelter in 1983 after they developed the Water and Habitat Unit.[10] Shelter as an aid has been provided by UN agencies or non-government organizations for the past 75 years.

There are numerous obstacles that need to be overcome when shelter is offered as an aid. Claims to land and land rights will lead to a lengthy legal process of identifying the land's proper owners. This process has a track record for slowing down the pace of reconstruction. Issues often arise about how to address those recently displaced and do not hold proper land claim titles.

Large expenses involved with the cost of providing shelters include: the procurement of materials, logistics, and an organized framework for distribution to those in need after a disaster. Other associated costs that must be absorbed by the donor organization pertain to: building storage warehouses or renting warehouses to store building materials, training volunteers with construction techniques, shelter design costs, purchasing equipment needed for construction, etc.

The costs associated with providing shelter has meant that some agencies do not involve themselves in it at all.

Many humanitarian organizations will distribute emergency shelters or shelter materials. Few venture into constructing semi-permanent (transitional shelter) or permanent dwellings.[11] Some notable international providers of shelter (for a variety of phases) are: ICRC (International Committee of the Red Cross), IFRC (International Federation of Red Cross and Red Crescent Societies), Oxfam, UNHCR (United Nations High Commissioner for Refugees), UN-Habitat, and Habitat for Humanity.

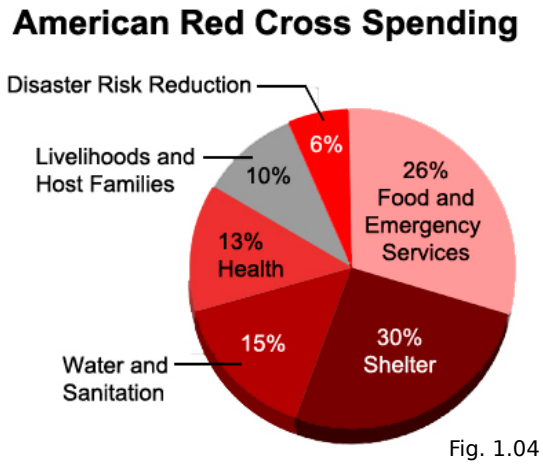



Fig. 1.04

Fig. 1.04 (left)
American Red Cross spent $28.6 million on semi-permanent shelter for 40,000 people and committed to provide shelters for 165,000 people total. $23 million to provide tarps, tents and tools for 625,000 people.[12]

Image A03 (opposite left)
Photographed by Dr. Jean Clottes at the caves of Bhimbetka, India. This painting is amongst 20 others of the same period.[8]

Image A04 (opposite right)
The oldest house in the world is dated to 15,000 years ago constructed of mammoth bones. This primitive tent was found near Kiev at Mezhirich in the Ukraine. It was included in the 1996 Treasures of Ukraine Exhibit at The Royal Ontario Museum in Toronto.[9]

A03

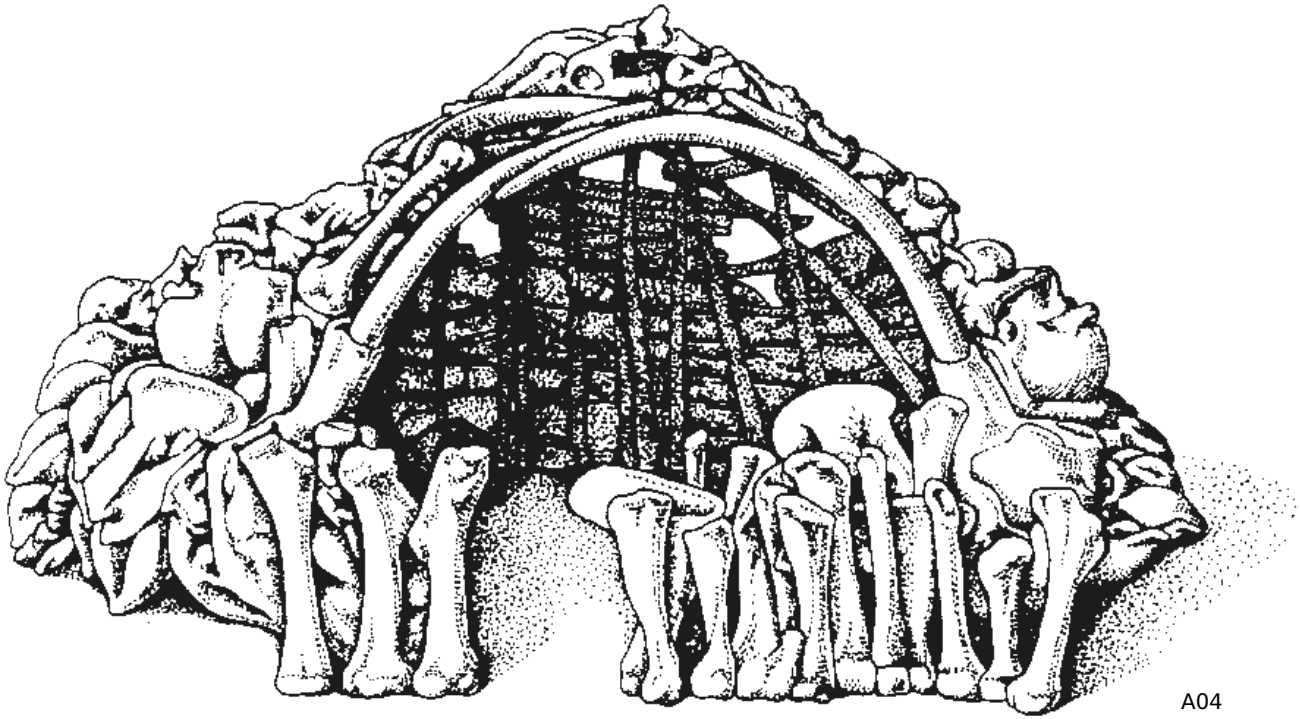
# Tent History and Architectural Significance

"The tent is in essence a biological, non-technological or primordial technology type. With the human, the tent became technological. It became a house, a locus of "living", the first bearer of culture, consciously passed on from generation to generation and increasingly refined." -Frei Otto[1]

The first recorded use of tents happened in the caves of Bhimbetka, India. It is a painting of two people inside a tent and is dated somewhere between 12,000 to 2,500BC.[2] The ancient Sumerians were the first to use the term in their language as the word zalam or zalamĝar around 2900BC.[3] The first written work mentioning people dwelling in tents is somewhere between 1450-1410 BC[4] in the book of Genesis. "A man named Jabel who lived in a tent while tending his cattle." (Genesis 4:20)[5]

Archaeologist Jacquetta Hawkes has stated that Cro-Magnons have used them earlier than 20,000 BC.[6] These tents were made of mammoth tusk and hide. Such discoveries show that tents have been around for well over 20,000 years. Tents share the title of being one of the first building typologies alongside crude stone masonry and primitive huts.

The term tent did not come into the English language until the 14th century. It was derived from the Latin term tenta, which was feminine of tentus, and the past participle of tendere to stretch.[7]



A04



Marcus Vitruvius Pollio, Marc-Antoine Laugier, Gottfried Semper, and countless others wrote on the important role that tents had contributed to the field of architecture.

Vitruvius was the first to write about the importance of the primitive hut in his treatise on architecture called De architectura. He believed that when man created fire, language and social interaction were born from this. This new form of communication begot competition with quality of shelters between primitive men. Some used mud others used reeds. Each shelter was improved upon almost daily. Vitruvius stated that houses originated from primitive shelters, and he referred to the homes which foreign tribes like the Gaul, Spanish, and Portuguese built as evidence.[10] He was not concerned with what architecture was, rather to show the process of where and how architecture reached its present form.[11]

Laugier was the first Frenchman to oppose Vitruvius' theory about the creation of a primitive hut. He theorized reason to be the sole guide for decision making within architecture and that the primitive hut must have been constructed using

logic.[12] When referring to the shelter's construction Laugier stated: "the parts that are essential are the cause of beauty, the parts introduced by necessity cause every license, the parts added by caprice cause every fault."[13] To Laugier this was perfect architecture, an architecture of necessity.

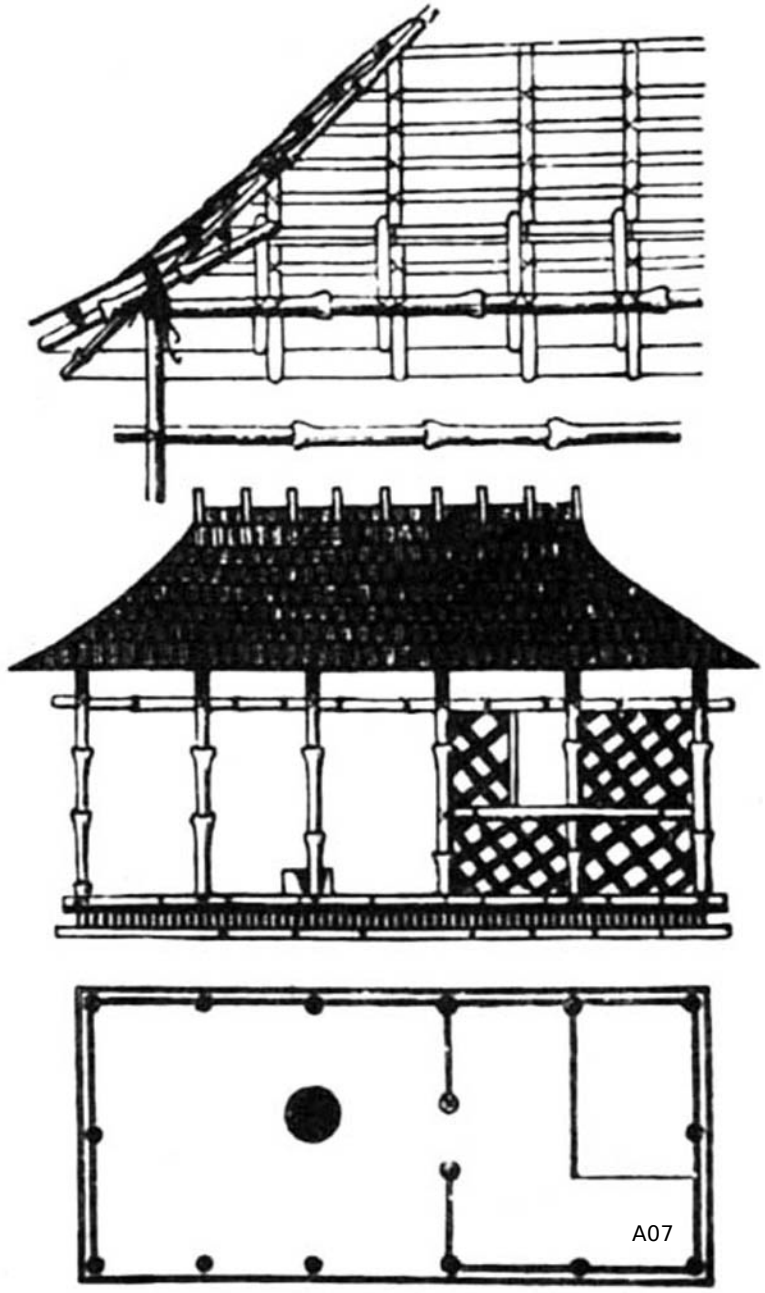
Semper may have agreed with Vitruvius that language and architecture were two civilizing institutions for human culture. He rejected Vitruvius' weak link made between the primitive hut and a Greek temple arguing that there is no evidence of architectural evolution into this scheme/typology.[14] He was interested with the tent typology and found in it all the elements of architecture. Semper believed that the hearth, the earthened platform, roof and columns, and the wall, which was made of textile hanging, are the four elements that constituted a house.[15]

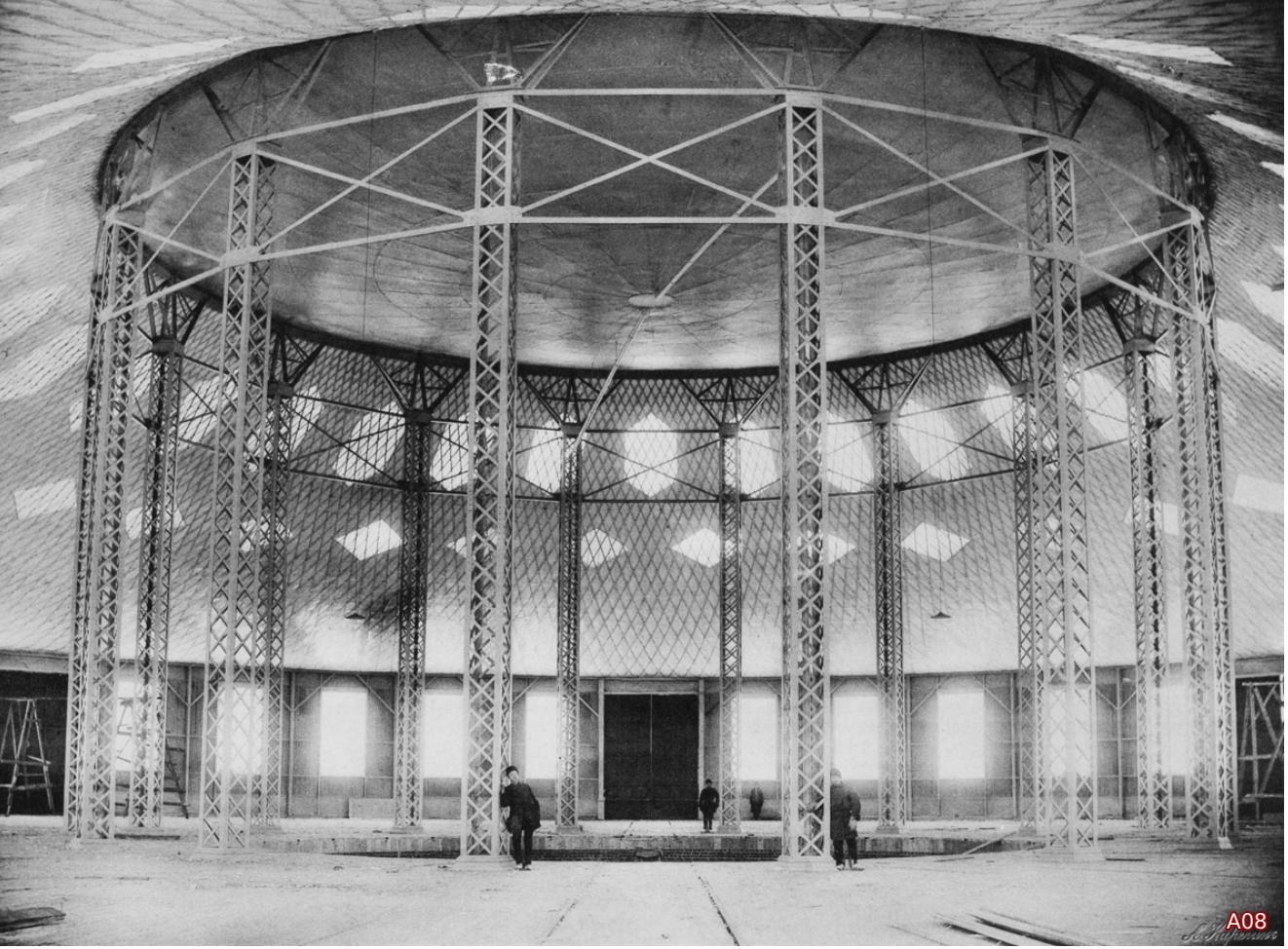
Vitruvius, Laugier, and Semper may have been intrigued by the functionalism of primitive dwellings, they wrote about such shelters with the intentions of forwarding the popularity of their own architectural ideologies.

Image A05 (opposite left)
"Illustration of the Primordial hut"
for Vitruvius' *De architectura*.

Image A06 (opposite right)
Frontispiece image on Laugier's 1755 English
edition of *Essai sur l'architecture*.

Image A07 (right)
Gottfried Semper, Caribbean Hut,





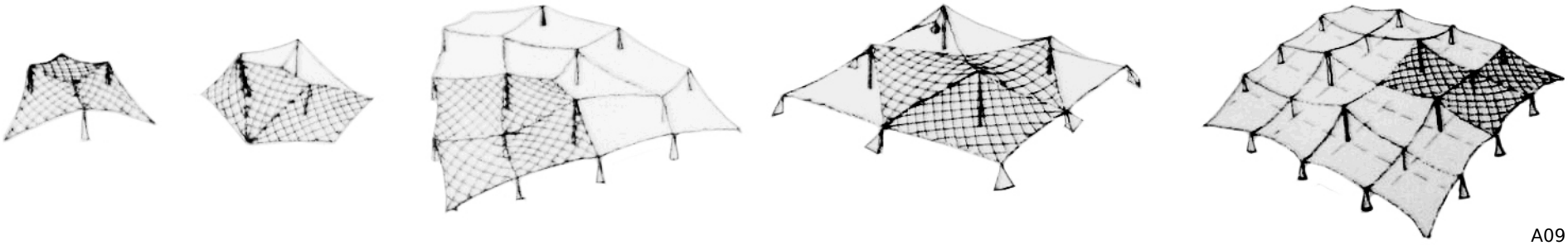

Fabric architecture remained relatively unchanged up until 1895, when Vladimir Shukhov designed the world's first fabric membrane roof on the Shukhov Rotunda and world's first tensile fabric roof for the exhibition hall at the All-Russian Exhibition of 1896 in Nizhny Novgorod.[16] Shukov's main goal was to create roof systems that minimized the use of materials, time, and labour.[17]

Frei Otto has made a strong impact promoting the use of fabric tensile architecture since 1950. His published doctoral thesis Hanging Roofs in 1954 continues to this day as a very influential piece of architectural literature.[18]

There was a problem associated with the first large-scale fabric roofs: replacement had to be done periodically (roughly every 3-5 years).

Image A08 (left)
Shukhov Rotunda, Nizhny Novgorod

Image A09 (below)
Sketches from Frei Otto's doctoral thesis *Hanging Roofs.*



A09



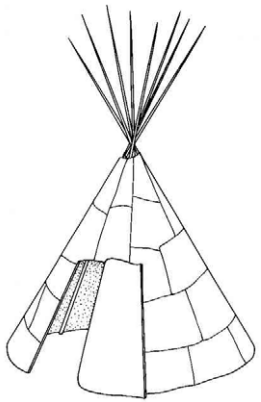

That changed in 1969 when DuPont teamed with Owens-Corning, Chemfab, and Birdair to create fibreglass fabrics coated with Teflon. The developers of this material have projected a minimum of 20-year life span. This invention has introduced a new type of architectural typology: durable fabric architecture.

Teflon coated fibreglass was first used at University of La Verne Student Centre, La Verne, California and designed by John Shaver in 1973. The original fabric has yet to be replaced.[19] Without the development of this material, buildings such as the Millennium Dome or Burj Al Arab would not be possible.

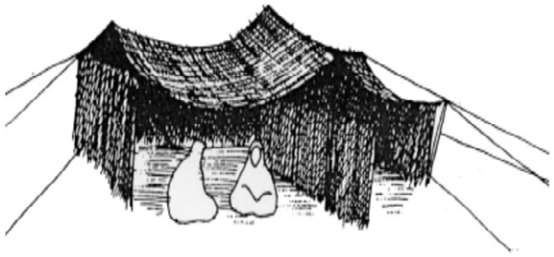
Image A10 (left)
La Verne Student Center

Image A11 (center)
Millennium Dome

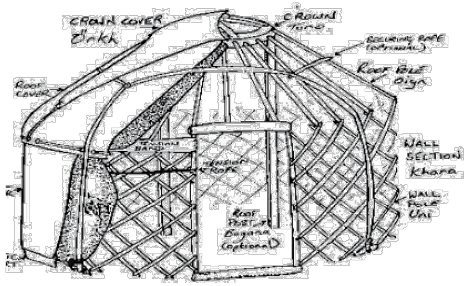
Image A12 (right)
Burj Al Arab



A13



A14




A15

# Global Tent Typologies

Today there are as many variations of the tent as the tribes and cultures that use them. It is a globally accepted dwelling which is best utilized by nomadic people. Abdul Hai Yousufi (Delft Technical University, Netherlands) has thoroughly documented tent typologies across the globe and has divided the world into several predominate tent zones. These are areas of the black tent (Arabian, Afghanistan, Iran, Middle East, North Africa), North Eurasian tent (Siberia, Mongolia, Tibet) and North American tent. Some tents share similar characteristics in the assembly yet have unique shapes that may be better suited for its intended climate or region. Mr. Yousufi has mentioned 46 tents in his book *Fabric Structures* and undoubtedly does not mention all the variations found across the globe.[1]

Tents worth mentioning are the teepee tents (cylinder-conical) most commonly found in North America, black tents found throughout regions of the middle east, and yurts (latticed or unlatticed) which extend from Siberia to Mongolia.[2] World Vision Canada supplies a tent called a 'ger'

Image A13 (left)
Teepee of North America

Image A14 (center)
Black tent of the Middle East

Image A15 (right)
Yurt of Siberia, Mongolia, and Tibet


(yurt) for families in Mongolia for a donation of $900 CAD as a cold climate shelter.[3]

During a study of shelters used by displaced populations in Afghanistan, it was noted that a tent called 'kuchi' (Image A16) was an extremely robust and adaptable shelter made of woven goat hair on a wooden frame. This skin was thick enough to repel water and provided adequate insulation against both hot and cold temperatures. There was interest in this tent for mass production.

Regrettably, this tent required vast amounts of goat hair, which were unavailable in large quantities from local supplies. Furthermore, this tent weighed several hundred kilograms in total and greatly inhibited ease of transportation.[4]

# Tent as Choice

"Consider first how slight a shelter is absolutely necessary... I have seen Penobscot Indians in this town, living in tents of thin cotton cloth, while the snow was nearly a foot deep around them, and I thought they would be glad to have it deeper to keep out the wind." - Henry David Thoreau[1]

Right now, over a hundred million nomads (itinerants) live across our globe.[2] There are three distinct types of nomads: hunter gatherers, pastoral nomads, and peripatetic nomads. Hunter gatherers and pastoral nomads both in some way deals with agriculture, raising livestock, or hunting as a means of life. While peripatetic nomads offer services (technical, entertainment, trading, etc.) to urban areas as they travel from town to town.[3] There are 30-40 million nomadic pastoralists living in our world today, the majority of them choose to live in light weight shelter solutions or tents (this number does not take into account people in the world who are living in a tent as a refugee or internally displaced person, those who dwell in tents with no other choice).

Lightweight shelters like the yurt are common dwellings for the 30% of the population of Mongolia. People who live in yurts are a part of Mongolia's 15% GDP livestock industry, which also accounts for 34% of Mongolia's labour force.[4] 80% of Mongolia's countryside is covered by grassland, which can support the 35 million horses, cattle, sheep, goats, and camels that graze within its territory borders.[5]

The 2012 National Geographic Traveller Photo Contest winner was a picture (Image A19) of two ladies inside a family yurt at Kyrgyz lands of the Wakhan Corridor, Afghanistan.[6] This family like much of today's nomads has touches of modernity in their lives. Their tent is fitted with solar panels to power their television, radio and charge their mobile phones. Today most nomads use vehicles to help transport their goods and possessions across the land.

Unfortunately, the pastoral nomadic lifestyle is on the decline. By 2015, China plans to settle some 1.16 million nomads freeing up grazing land for development.[7] Mongolia over the past eight years has opened up numerous acres of grazing land for mining and plans to expand their mining industry further.[8] Long spans of drought causing deadly conflicts between herdsmen and increasing tensions with farmers has decreased the number of pastoral nomads who roam between Ethiopia, Kenya, Somalia, and Sudan.[9] Bedouins of Saudi Arabia, Iraq, Iran, and other Middle Eastern Countries have a handful of nomadic herdsmen left. Most have been assimilated into a more modern lifestyle or the expansive development of urban centres has made it increasingly difficult to herd livestock.[10]

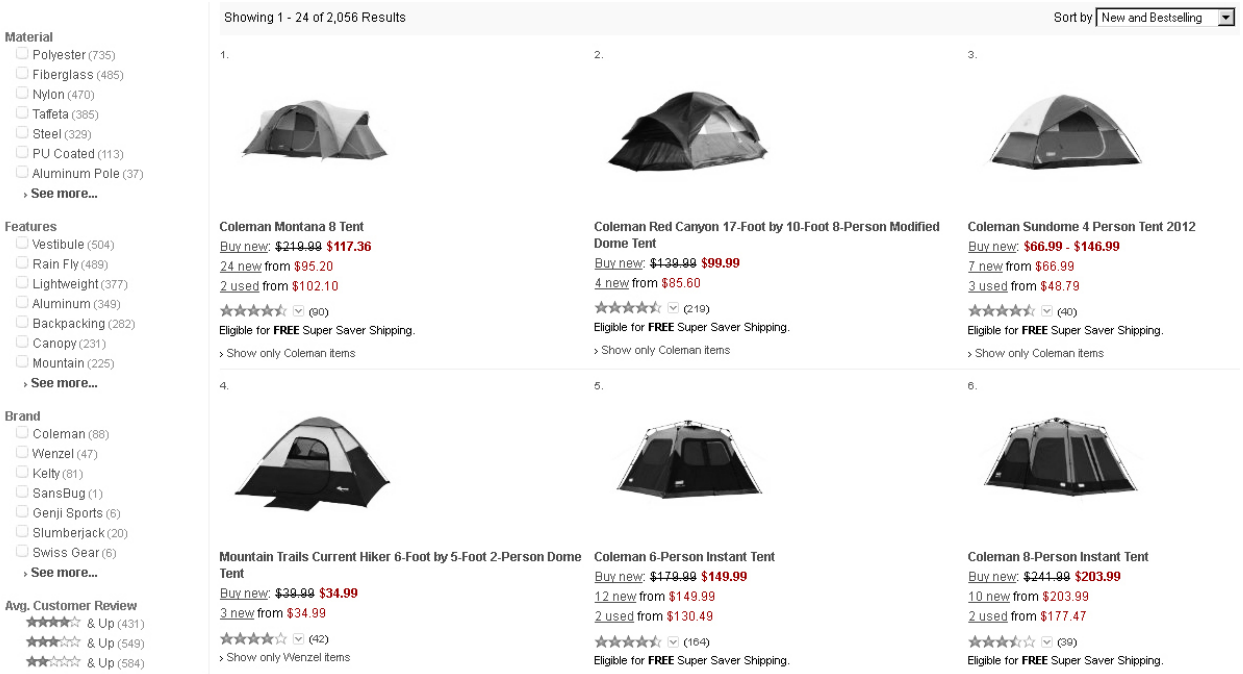
The global dwindling of the pastoral nomad population might mean that the tent will not hold the same importance as a dwelling choice as it once did. In the future, tents may be relinquished from its permanent housing status and only categorized as being a shelter for recreation or humanitarian relief.



Image A17 (right upper)
Nomads living in Inner Mongolia grasslands outside of Chifeng, China

Image A18 (right lower)
Israel government will be evicting as many as 40,000 Indigenous Bedouins from their ancestral lands.


A19




A20

A21

# Current Tent Technologies

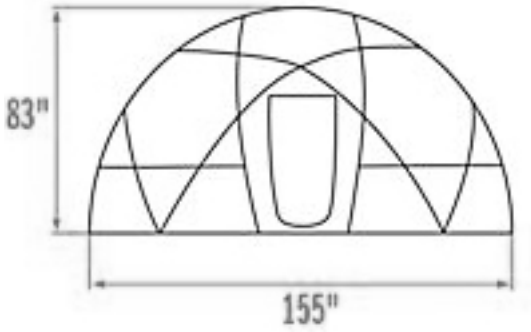
Contemporary tent manufacturers offer numerous styles appropriate for various applications. Some of the most popular tent manufacturers in North America now include: Coleman, Eureka, Golite, Kelty, Cascade Designs, Sierra Designs, Columbia, North Face, Hillary, Marmot and Mountain Equipment Co-Op.

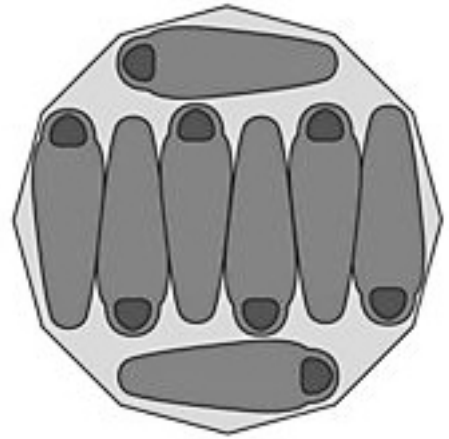
Some brands such as Eureka began their tent line with a canvas tent, and in 1960 transitioned to synthetic material which was nylon coated with waterproof urethane . Eureka tents have been on the summit of Mt. Everest more than any other brand.[1]

The most recognized tent brand in North America is Coleman. Amazon.com has sold outdoor sports equipment before 2000, a Coleman shade tent is the best-selling tent on that website. Coleman occupies fourteen slots on in the list of top 20 tent products on amazon.com (accessed July 2012). Their products are currently situated at 63 and 82 on the top 100 in sports & outdoors category. None of their competitors are above this position and no tent competitor made the top ten (July 2012).[2] Coleman tents offer a broad range of options, however, it is more suited for the novice or family campers. Coleman's products are also inexpensive, which may attribute to its high volume of sales.

One of the most expensive tents on the private market is the 2-Meter Dome by North Face. It retails at roughly $5,500 CAD excluding taxes.[3] This tent is designed for major expeditions in the Himalayas or Antarctica. Mountain Hard Wear offers a similar tent for roughly the same price called the Space Station.

Today's retail tents are made from synthetic materials such as nylon (also referred to as ripstop nylon), polyester, polyethylene, and polyurethane are added sometimes as coatings for waterproofing. The Coleman products offer polyester walls with polyurethane for waterproofing. Their heavy-duty



A22

## 2-METER DOME

**$5,000.00**

**Style** A557

Be the first to write a review

**1 Colors:** GOLD / WHITE / BLACK

**Size:** ONE SIZE

ONE SIZE

QUANTITY: 1 ADD TO CART

## FEATURES

- Hemisphere shape demonstrates the original geodesic dome principle developed by Buckminster Fuller
- Easton 7075-E9 aluminum poles
- Pole configuration creates steep walls and maximum user space
- Two exterior windows and a chimney vent
- Interior canopy loops
- Dual doors
- Summit Series® collection
- *Gift box not available for this item

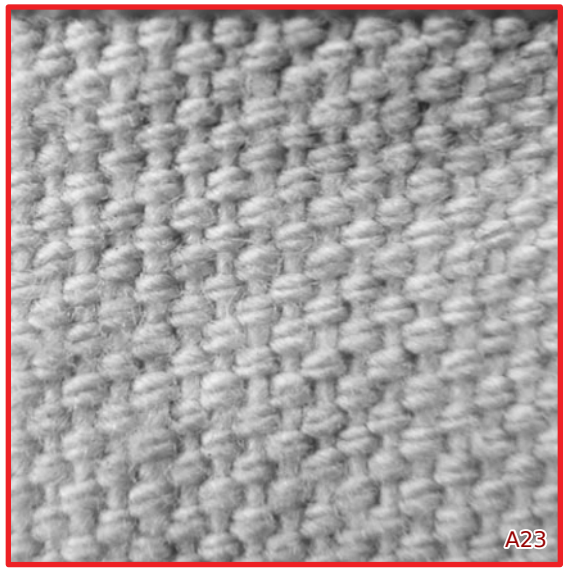
SUMMIT SERIES

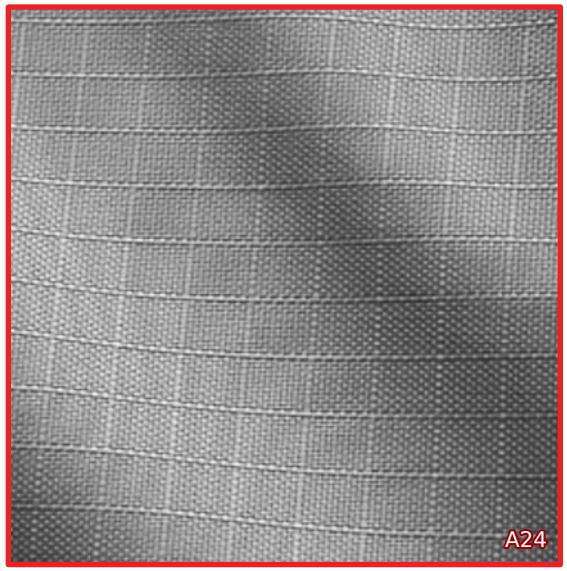
Athlete Tested. Expedition Proven. Best-in-class outdoor gear and apparel. Period.

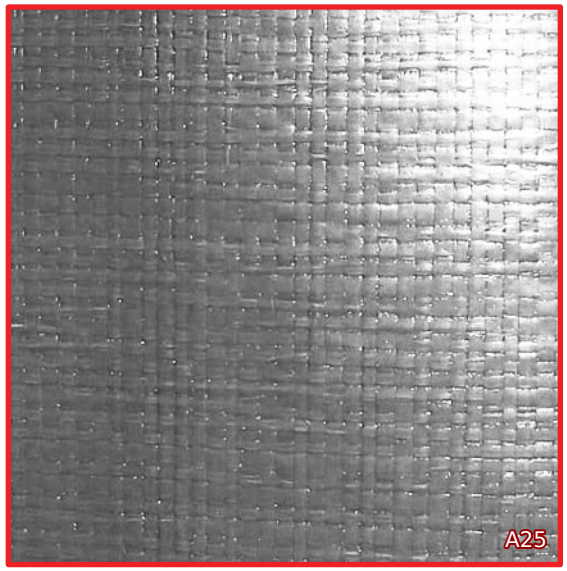
Image A20 (opposite left)
Coleman Road Trip Beach Shade
Amazon Best Sellers Rank: #63 in Sports & Outdoors (See Top 100 in Sports & Outdoors) #1 in Sports & Outdoors > Outdoor Recreation > Camping & Hiking > Camping Shelters

Image A21 (opposite right)
Screen shot of tents category for *amazon.com*
July 2012.

Image A22 (above)
Adjusted screen shot from
the North Face website.




tent series offers 150 D fabric and stated that it was twice as thick as the standard tent material. The expensive 2-Meter Dome tent manufactured by North Face offers a 210 D nylon wall, which is still considered a light-weight fabric.

The higher the denier number (D after the thread count number) the greater the thread diameter is in the weaving, leading to a stronger fabric. Larger denier values lead to increased fabric weights as well.

Current tent manufacturers offer taped seems, which eliminates the use of the rain fly. Poles are generally made from aluminium, galvanized steel, or fibreglass. The support frames of contemporary tents are often located on the exterior of the tent. This is opposite to almost all nomadic or tribal tents. Polyethylene is specified the most for floors due to its resistance to punctures more so than polyester or nylon.

It is rare to find a tent made of canvas on the consumer market. All the top tent manufacturers have stopped production with canvas models. Canvas tent materials are typically used in military or relief shelter situations. Nylon or polyester, which has replaced canvas, has dramatically changed the tent industry in terms of weight.

Synthetic materials like nylon or polyester are over 80% lighter than conventional canvas used in tent making.[4] This decrease in weight has allowed the consumer to carry their larger family tents with them on foot, whereas, a canvas tent would have required cart, sled, or aid of a second person to carry. The nylon or polyester that has replaced canvas is more susceptible to puncture. Heavy duty canvas also has a higher resistance to tearing or splitting.

At present, tents that are manufactured for the commercial market offer no models that are resilient enough to withstand the requirements of a long term shelter solution.

Section summary:
Light weight shelter solutions are extremely useful after disaster situations. They have been a proven shelter typology for thousands of years. New material development can push this form of shelter into a semi-permanent solution.

In next section:
The will be an expansion on how humanitarian organizations provide shelter solutions today. Perspectives from both the donor and the receiver will be presented. The most common humanitarian shelter provisions are reviewed.

Design considerations:
- tent selected as shelter solution for development
- high-tech fabric will be analyzed to potentially increase permanence/durability
- investigate global tent typologies vs market tent design

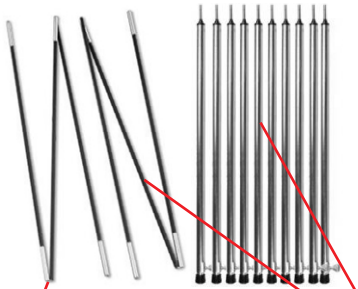
## Today's retail tent technology includes:
(Coleman's Red Canyon tent shown)

-taped seams or reinforced waterproof seam (Seam Grip shown)


-40 D to 220 D nylon or polyester fabric walls

-polyurethane waterproof coating on wall material

-polyethylene, nylon or polyester floors (thicker than wall material with higher polyurethane wall proofing value)



-poles are made from galvanized steel, aluminium, or fibreglass

-poles have elastic cords running down the centre for added assembly speed and to prevent pole section loss

-can be erected in minutes

-can accommodate up to 12 persons

-are tailored for either 2, 3, or 4 seasons

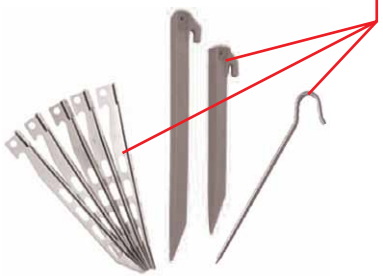
-structure located on exterior for quicker assembly

-some are stove friendly (expedition tents)

-seamed and protected zippers for added waterproofing

-convenient travel bag for tent storage and transportation

-tent pegs are made from galvanized steel, aluminium, and plastic at lengths up to 18"



A26

Image A23 (opposite left)
canvas

Image A24 (opposite centre)
ripstop nylon

Image A25 (opposite right)
polyethylene sheet

Image A26 (above)
Current technologies that are available in the retail tent market.

## Natural Disasters: A Global Analysis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# APPROACHES

# The Economic and Human Impact of Disasters in the last 12 years

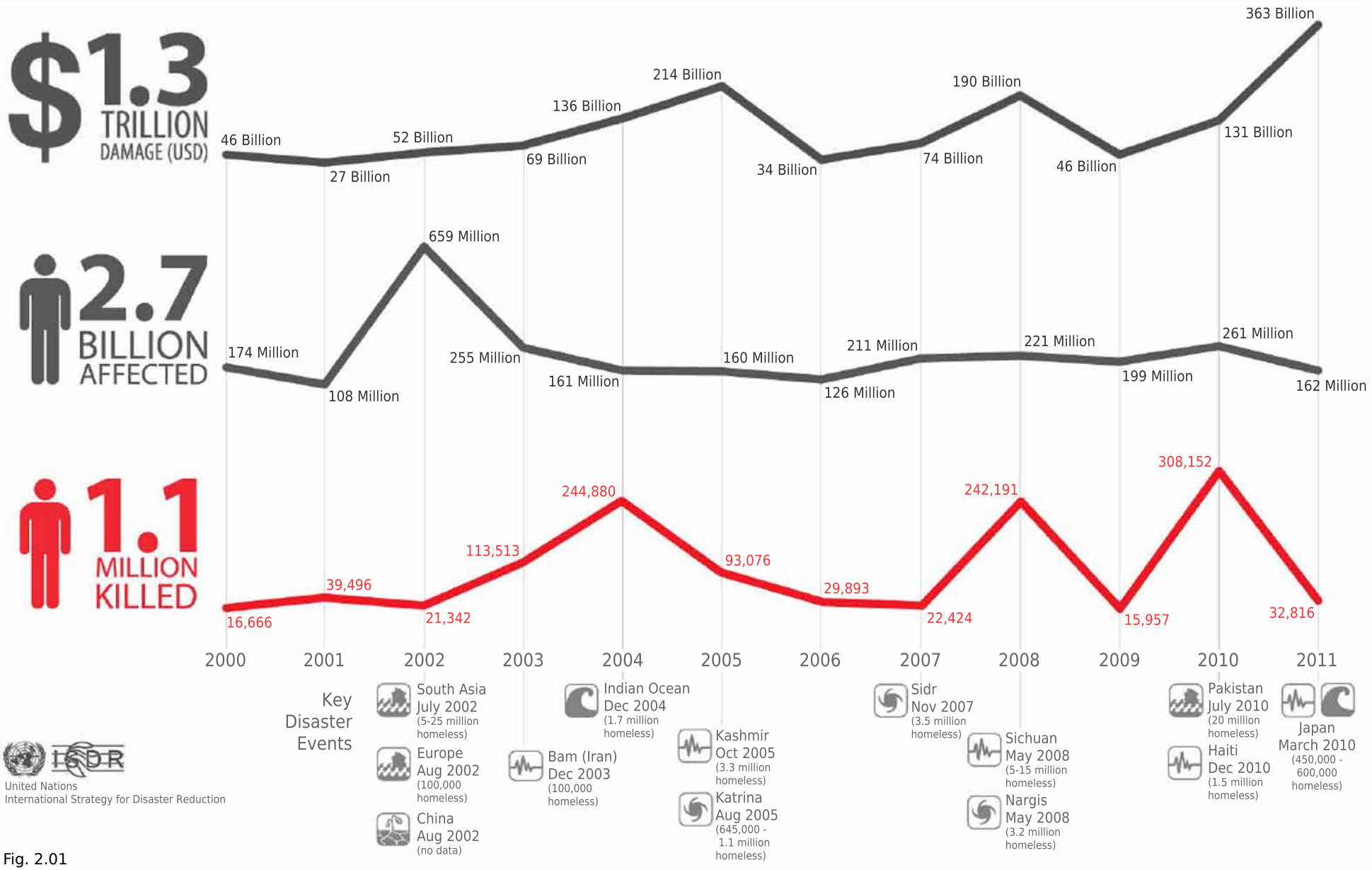



Fig. 2.01

# Addressing Homelessness

"The humane desire to lighten a little the torments of all these poor wretches... creates a kind of energy which gives one a positive craving to relieve as many as one can." - Henry Dunant[1]

Emergency shelter, transitional shelter, and permanent reconstruction currently are the three strategies humanitarian organizations address those displaced after a disaster. Each of these solutions addresses the different lodging needs. Emergency shelter and transitional shelter are tied more to a rapid response, while permanent reconstruction is the end goal for most organizations.

Emergency shelter is provided by the donations of tents, shelter kits, shelter repair kits, or plastic sheets/tarpaulins. Their role will be to provide the disaster relief industry with rapidly constructed accommodations to house the displaced. These materials are typically supplied within the first two weeks following a disaster. People may wait up to a month for shelter depending on how the infrastructure is within the devastated region. In most cases, this solution is the least-expensive option, assuming material can be procured within the affected country. If not, then logistics costs increase greatly.

Emergency shelter solutions are considered to be temporary and should not be inhabited for durations longer than six months. Discouragingly, emergency shelters are sometimes inhabited for periods beyond the 12-month period. This happened in Haiti following the January 12, 2010 earthquake. Some Haitians have been living in squalid tents for over 23 months (as of February 2012).[2] [3]

During the course of this research some of the humanitarian agencies (USAID, IFRC, etc.) expressed the view that the status quo is acceptable. However, the design proposal in Section 5 (Application) will addresses this notion: the status quo is not acceptable and emergency shelter should not play a gap-filling role. Such a strategy should only be used if a clear plan has

(see page 46 for end notes)

Fig. 2.01 (opposite)
1 in 3 people worldwide are affected by natural disasters.


B01


48
B02


B03


B04


B05

Image B01 (opposite top left)
Small shelter repair kit provided by Found International.

Image B02 (opposite top right)
Emergency tent camp in Ezbet Abed Rabbo region, Gaza.

Image B03 (opposite lower left)
Transitional shelter built in Haiti following the earthquake of 2010.

Image B04 (opposite lower right)
NGO built permanent homes in Banda Aceh following the 2004 Indian Ocean Tsunami.

Image B05 (above)
Transitional shelter icons created by the Shelter Centre.

been made to address homelessness through rapid reconstruction.

Transitional shelter can be divided into four main types: type 1 upgradable, type 2 reusable, type 3 resellable, type 4 recyclable. Type 1 shelter can be upgraded to a permanent housing solution that replaces materials to the original shelter with durable/robust materials. Type 2 is a shelter will be reused for another purpose afterwards such as a chicken coop, storage shed, or guest house. This is long after the occupants have moved into more permanent construction. Type 3 transitional shelters would be taken apart, and the materials resold when the shelter is no longer in use. Type 4 shelters will have the building materials of the transitional shelter used in the construction of permanent housing.[4]

Another type of transitional shelter rarely mentioned by humanitarian agencies is the transportable transitional shelter. This shelter will be given to people that need to be relocated to a safer geographical location during the reconstruction process, or if shelters are located on property that has land claim issues. It should be constructed for refugees in hosting nations during disasters or conflict situations as well. Transportable transitional shelters will be relocated to the property of the occupants after the issues listed above have been resolved. This shelter could share similar aspects of types 2, 3, and 4 transitional shelters.

Another type worth mentioning that rarely is given credit from humanitarian organizations, is the transitional shelter that is created by the survivors themselves. These dwellings will be created by utilizing any salved bit of scattered material following the disaster. Almost 80% of the reconstruction effort is done by the affected population following a disaster.[5] This topic will be expanded upon in more detail in Section 3.

Permanent reconstruction typically begins a few months to a couple of years following the disaster.[6] Conditions of the affected region's infrastructure, the amount of funding accessible by government and donor sources, resolved land claim issues, availability of building materials within the affected region, and availability of both skilled and non-skilled labour force are factors that determine the speed of permanent reconstruction.

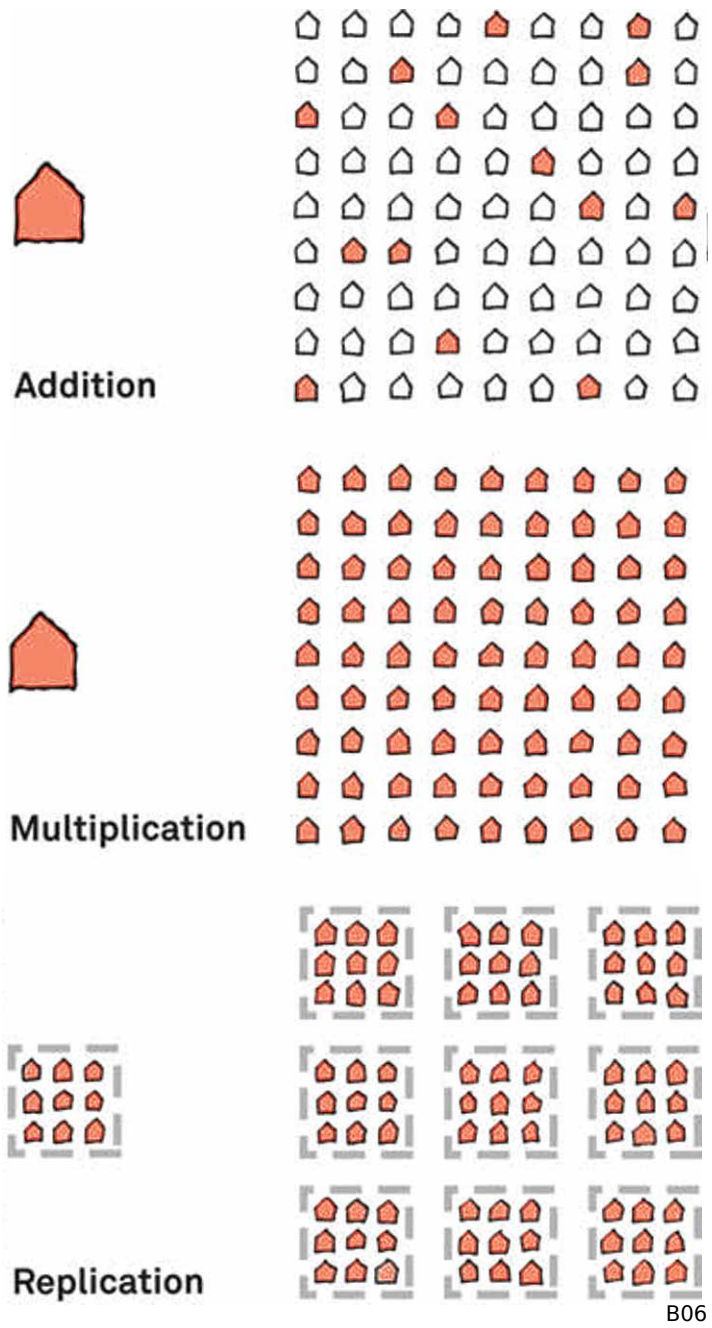
Several delivery methods used during reconstruction are: cash grants, materials for repair, donor or government provided permanent homes, donor or government rapid reconstruction strategies, and donor or government provided upgradable homesiii. Regardless, in most cases the affected population will reconstruct their homes

over a period of time.[7]

Although this thesis will not address in detail the methods agencies use to execute construction projects, it should be briefly mentioned. Donor organizations implement their reconstruction initiatives using addition, multiplication, or replication. Each of these procedures has their strong and weak points. Addition consists of constructing one or two homes within the vacant land scattered across the affected region. This mechanism does not require a lengthy agreement process and could be replicated quickly. However, several sites will be undergoing construction in parallel, which can be hard to manage. Multiplication involves the use of contractors to build hundreds of homes at once utilizing the same design and is very successful at being a rapid way to reconstruct. Multiplication is the least involved with the recipient. Replication is the middle ground between addition and multiplication. Homes are built in clusters of ten to twenty at a time. Communities are involved during the design of the model home for their cluster. This method requires a lot of time planning in the early phases.[8]

Image B06 (right)
Visualizing construction methods used by humanitarian agencies.

Image B07 (opposite)
Emergency kits provided by World Vision, to be distributed at Dadaab refugee camp in Kenya.



B06


B07

## Shelter as First Response

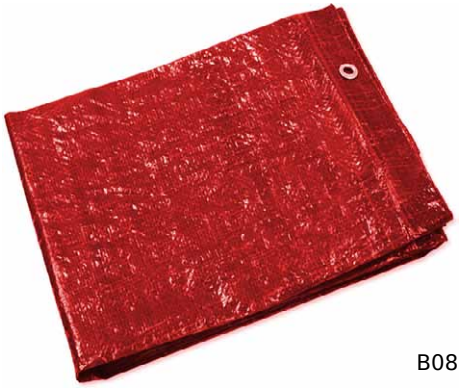
In 2008, there were 42 million forcibly displaced people (from conflict, natural disasters, etc.) worldwide. That includes: 26 million internally displaced people, 15.2 million refugees, 6.6 million stateless people, and 827,000 asylum seekers.[1]

After the first week, NFI (non food items) will typically begin to arrive in a region that was affected by disaster.[2] These items will include blankets, clothing, cookware and utensils, tools, water containers, plastic sheeting, buckets, matches, etc.

Humanitarian agencies offer four main types of first response emergency shelter: the tent, plastic sheeting, shelter kit, and shelter repair kit.

The shelter repair kit may not include building materials which will depend on the donor agency. Tools are provided to those who have the necessary materials to construct their own shelters and to homes that are in need of light repair.[3] It will include: a claw hammer, axe or machete, rope, different types of nails, washers, pliers, hand saw, and a shovel.

Shelter kits distributed by donors include the bare essentials for erecting an emergency shelter. Occupants will assemble these emergency shelters with rope, tarpaulin or plastic sheeting, and a metal, wooden or bamboo poles. Some agencies have a hybrid of both the shelter repair kit and shelter kit that provides tools with the shelter kit



B08

B08

kit or vice versa. Building materials such as corrugated zinc sheets, mosquito nets, and light lumber are periodically distributed as well. This will depend on the availability of materials, as well as the size of the donor agency's budget.

Plastic sheeting is the bare minimum of all emergency shelters provided by donors. Regularly distributed in two forms, the manufactured sheet that comes in standard packaged sizes or pieces that have been cut from a large roll of sheeting in the field. The distribution of plastic sheeting does not include poles or rope for individuals to use in combination for shelter construction. Recipients are expected to salvage whatever materials necessary to construct their temporary emergency shelter. Distributing plastic sheeting is a very effective way of providing shelter materials to as many people as possible.[4] Sheeting is the least durable solution. It will deteriorate within six months (most likely at the three month mark).[5]

Larger agencies have the budget necessary to distribute tents as an emergency shelter to those in need. There are numerous tent manufacturers who market shelter products for relief agencies having many different shapes, sizes, and materials to choose from. Of all the emergency shelter options, the prefabricated tent is the most complete shelter option. Contemporary tents have weather proof seams, windows for ventilation, and ground covering. They are adaptable for both hot and cold climates, depending on model style can be fitted with stoves.

As of right now tents are the highest priced emergency shelter option, costs starting in the hundreds and can easily exceed thousands. At present, the majority of tents have the life span of under a year (with the exception of military tents and those used for scientific expeditions). Most tents are not designed for long durations. Tents often suffer damage from over use, weather, and punctures from furniture.

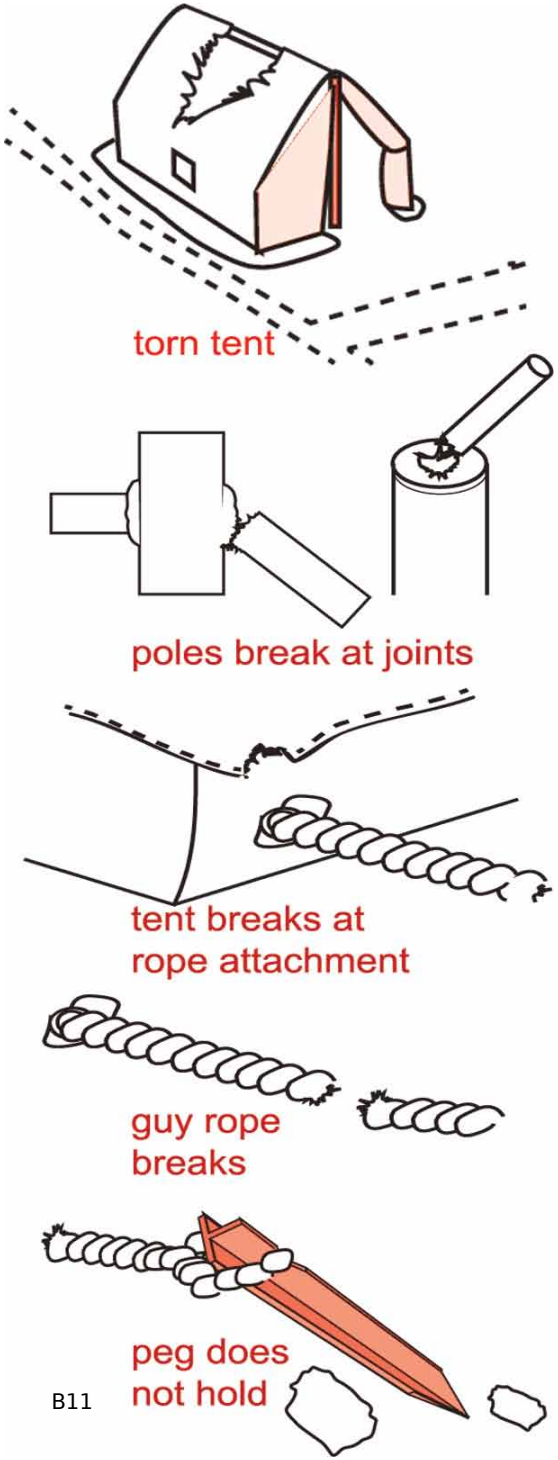
B10

Image B08 (upper left)
Tarpaulin sheet of predetermined sized used shelter material.

Image B09 (lower left)
Tarpaulin cut from a large roll also to be used as shelter material. Polyethylene tarp material lifespan: 3 months.

Image B10 (above)
A Haitian man packs emergency shelter kits for Catholic Relief Services at a warehouse in Port-au-Prince.

Image B11 (opposite)
Observed problems with disaster relief tents during field operations.



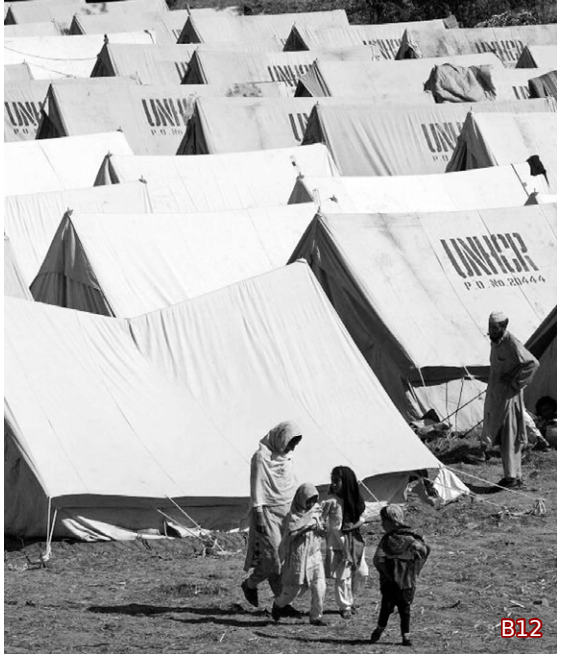
B11

# Overview of Relief-Supplied Tents

Relief tents come in a broad range of standards and vary in size greatly, from single person use to multifamily dwellings. They can range in quality similar to that of retail family tents or tents specified for military use.[1]

Some criticisms for relief tents supplied by donor organizations are: that they are inadequate in size per person[2], materials lack durable characteristics, and are not appropriate solutions for the climate/region.[3] When these emergency relief shelters become occupied, several typical failures occur. Rips in fabric under stress, rips along the seams of the fabric, poles snapping from excessive force/weight placed on them, snapping of guy ropes, guy ropes ripping material that attach to the tent, tears in openings from over use, pegs letting go, and tears caused from human use or interior furniture, all of which are reoccurring problems for relief tents.[4]

Emergency relief tents that are made from canvas (Image B12) may last the inhabitants beyond a year (only if conditions are favourable). Heavy duty cotton is a material more durable than nylon/polyester.[5] Canvas tents can rot from mildew (unless treated properly). This will greatly reduce their lifespan and limit reuse. This is a characteristic common to canvas tents.[6] Canvas



B12

treated properly for water and UV resistance has the capacity to last more than one year. It is relatively easy to repair with needle and thread as well. Heavy weight cotton tents will reflect more heat in comparison to nylon or polyester tents, making canvas tents cooler in temperature than those made of synthetics.[7] Due to weight, canvas shelters may require transport assistance.

Small tunnel tents (Image B13) in most cases are made from polyester/nylon while larger tunnel tents are made from polyethylene.[8] A tunnel tent generally resembles the shape of a greenhouse and is constructed in a similar fashion. The barrel design responds well against wind load. Water pooling will happen if erected improperly. Seams will be the first to fail with these structures if water pooling happens frequently.[9] The poles are made of galvanized steel, aluminium, fibreglass, or PVC plastic.


The high-quality frame tent (Image B14) is the preferred choice after a disaster. UN, Red Cross/ Crescent, Oxfam, Etc. all supply similar tents of this quality. These tents are made with treated canvas or a canvas with a synthetic covering, and the frames are metal. These structures may last beyond a year for their occupants. Recipients often complain that frame tents become unbearable for use during the day within hot climates.[10]

Common retail tents (backpack/hike tents) (Image B15) are also supplied to areas after a disaster (recently to Haitians after the earthquake) and range in size from tents for single occupants to sizes appropriate for five to six people. Unfortunately, these tents do not last long. Most fail before six months of use (in Haiti some lasted only two weeks).[11] Thin fibreglass poles splinter or snap and fabric gets torn from furniture puncture. These tents are marketed and sold for normal family camping excursions, not relief shelters.



Dome tents (Image B16) are another category of tents supplied by donors. These tents can be made of synthetic fabric polyethylene, polyester, or nylon. The poles are made of either fibreglass or PVC, and tents have a life expectancy of six months. The dome tents made with PVC exterior poles will warp in the sun's intense heat, this leads to early failure (Image B17) in hot climate zones. failure in hot climate zones. Dome tents are also considered to be boiling during the day by their occupants.[12]



Multiple unit tents (Image B18) used to host several families are also erected at sites following a disaster. These tents may have been used by the military at one time or can be purchased for around three to six thousand US dollars from companies like NBC Group or MDM Shelters. These tents are made from very high-quality

materials and will last long periods of time for those dwelling inside. These tents may require some maintenance and will not fail early if properly maintained. Many of these tents will be reused as hospitals, schools, public buildings, etc. Common complaints about large-sized communal tents are the lack of privacy for those for those that dwell inside.[13]


B18

## Cost of Example Relief Shelters

"Rather, for all objects and experiences, there is a quantity that has optimum value. Above that quantity, the variable becomes toxic. To fall below that value is to be deprived." - Gregory Bateson[1]

A brief overview and comparison of tent cost.

### Single Family Shelters:


B19

Western Wall Tent (B19) - $300
420g/m waterproof canvas
3m wide, 4m long
1m sidewall, 2.5m center height
floor area: 12m² (6m² below Sphere Standards)
ropes, poles, stakes included
180 in a 20ft container; 360 in 40ft container
expected duration – 1 year
reusable - frame


B20

Disaster relief tunnel tent (B20) - $300
170g/m waterproof/fireproof ripstop polyester
2.5m wide, 4m long
2m center height
floor area: 10m² (8m² below Sphere Standards)
ropes, poles, stakes, ground cloth included
300 in a 20ft container; 600 in 40ft container
expected duration – 6-9 months
reusable - unlikely (frame if made from metal)

## Multi-Family Shelters:

B21

M-1945 Traditional Command Post Tent (B21) -
$435 used or $975 new
333g/m (vinyl coated polyester duck)
3.0m wide, 6.3m long
wall height 1.67m
floor area: 15.9m² (2m² below Sphere Standards)
2 rooms, vestibule is 4.45m²
windows and sashes to close them
expected duration – 1 year plus
reusable - frame


MDM Disaster Relief Tent (B22) - $4956
5.5m wide, 9.75m long, 4.5m high
UV protected PVC material 610g/m weight
floor area: 53.5m²
two (2) PVC fabric doors w/ screen
heavy duty 1 5/8" dia. structural steel frame, doublefly cover design, Velcro windows w/ mosquito screen, roof truss and removable center supports, fabric floor kit included, complete anchoring system, 610g/m CPAI-84 PVC vinyl cover and doors
expected duration – 1 year plus
reusable - high probability (entire shelter)
*requires interior partitions


Military surplus GP Medium Tent (B23) - $1990
4.85m wide, 9.75m long, 3.15m high
416g/m vinyl coated polyester duck
floor area: 47.57m²
available in canvas or vinyl, includes ropes, poles, tighteners, two stovepipe shields, sidewalls roll and tie up, transport/storage cover
expected duration – 1 year plus
reusable - high probability (entire shelter)
*requires interior partitions & ground cloth


Image B24 (upper right) Macasandig gym after 40,000 families from Cagayan de Oro, Philippines are affect by Typhoon Washi in December 2011.

## Evaluation and Criticism of UN/NGO Supplied Shelter

"The charity that hastens to proclaim its good deeds, ceases to be charity, and is only pride and ostentation." - William Hutton[1]

Large multifamily shelters are the highest in construction quality for emergency shelters compared against others within that category. Although this is true, many psychologists and sociologists believe this should be a last resort solution.[2] Shared multifamily spaces can lead to social breakdown, especially following a disaster.[3] Multifamily dwellings have been shown to escalate isolation, weaken community relations, and increase the breakdown of family structures. Most of these symptoms are due to overcrowding.[4] Evidence of these types of reactions occurred at the communal emergency dwellings in Mexico, Columbia, and Turkey following their disasters.[5] Many people believe that large community structures are more cost-efficient in comparison to several smaller emergency shelters housing the identical number of people. A few light-weight shelter solutions accommodating the same number of people may yield the same cost (Fig. 5.04) and have better social results.

In Haiti, many of the retail tents supplied by donor organizations failed beyond repair.[6] Retail tents that are designed for long habitations will be

outside of a humanitarian organization's budget (i.e. North Face expedition dome tent is $5,000 USD). There are other reoccurring problems with tents supplied by humanitarian organizations and how beneficiaries pitch them. Some tents fail early from improper assembly.[7] Some beneficiaries place their tents in low-lying areas that can potentially flood. This could have a disastrous effect on canvas tents, thus shortening their performance lifespan. Mistakes are easily avoided when proper instructions are given on site selection and how to pitch the tent.

Most complain of the intense heat caused from tents made from synthetic materials.[8] The majority of tents are not designed with proper ventilation in hot climate regions, while tents in cold climates are criticized for their inability to retain heat.[9]

Tents are lightweight shelters. They are adversely affected by high winds. Tent stakes rip out of the ground. Guy ropes have been known to snap or tear tent fabric where connections are made are common problems high winds have on tents.[10] Doors and openings often fail, Velcro clogs, and zips break, eyelets also tear where ropes are used to shut openings.[11]

Tents give the a sense of false security to those who dwell inside.[12] They are susceptible to many dangers,[13] [14] which will be explained further in Section 3 (Consideration) - Addressing Security.

It is difficult to find documentation from

Image B25 (lower left)
Example of a wind damaged tent in Abbed Rabu, Gaza.

Image B26 (lower right)
Flooding at relief camp after Hurricane Thomas in Leogane, Haiti.

Image B27 (centre)
How zips typically break on tent door openings.

Image B28 (opposite lower left)
Rotting of a canvas tent due to excessive moisture exposure and mold damage.

Image B29 (opposite lower right)
broken fibreglass tent pole

Image B30 (opposite upper right)
Mold damaged and ripped refugee tent located outside of Nimule, Sudan.

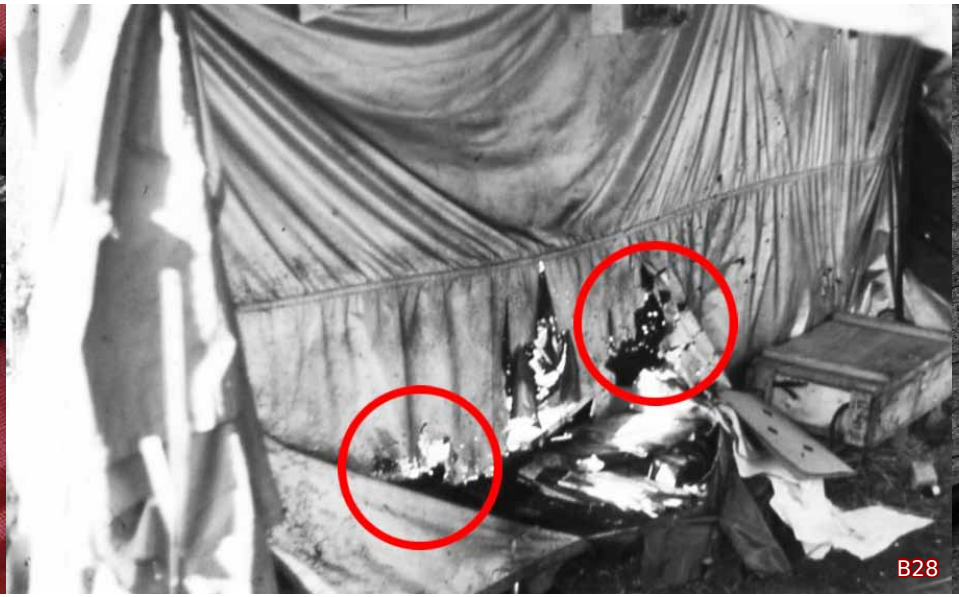


humanitarian organization websites that show negative perspectives from beneficiaries. Criticism of the tent quality/deficiencies listed were found in articles or reports from numerous news agency's web content. The humanitarian field does not publish criticism from beneficiaries against their relief strategies.

Most tents sold in the relief market do not have the qualities needed for people to inhabit these shelters for a long span of time. The majority of tents provided by humanitarians fail before the completion of a year.[15] [16] Beneficiaries who meet the requirements for the provision of an emergency relief shelter will be given a shelter that will not last the required amount of time.

B30


B27


B28


B29

# Comparing Tents and Tarpaulins

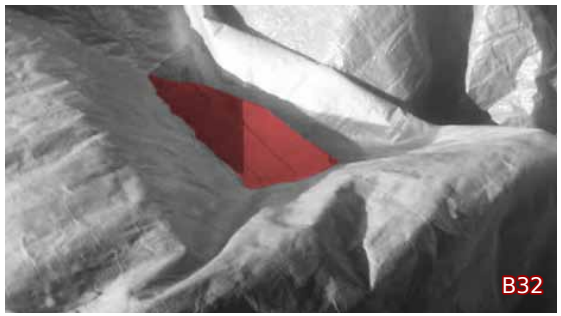
Much debate within the humanitarian community surrounds which type of relief shelter should be distributed to those in need following a disaster: the tent or a tarp? Both can offer reasonable shelter to the displaced, and each can be erected somewhat quickly. There are some very contrasting differences between these two solutions. In the first initial phase of disaster-relief, tents are the preferred shelter solution from most beneficiary's opinion. Tents are sometimes so preferred over other emergency shelters that after the Van earthquake in Turkey, the Turkish Red Crescent society had a shortfall of over 120,000 tents.[1]

In Haiti, the tent was seen as a clean and more modern way of living shelter solution. It was the culturally preferred alternative to tarps fixed on brush poles. The tarp shelters made the Haitians feel that they were returning to village living.[2]


Tents can be erected much more quickly than a self-made tarp shelter (Image B34).

While in Haiti, USAID (United States Agency for International Development) has taken credit for the distribution of tarps rather than tents, stating that the agency is thinking outside of the tent.[3] Some humanitarians believe that a tarp-built structure will be more durable, due to polyethylene sheets being more robust than the ripstop nylon material used in retail tents. Theoretically, less rain water will penetrate these structures compared to tents.[4]

Many Haitians have experienced first hand that these shelters fare worse in the rain compared to




tents.[5] They had to cut holes in the roof of their tarp structure during intense rain to release the pooling water (Image B32).[6] Beneficiaries in Haiti have stated: "Look at this," said Jean Theodore, a 64 year Haitian man, pointing to his tarp roof "As soon as it rains, the water drips right through. We want a tent."[7] Another man stated: "With a tent, you can close it and stay inside, so you're safe,




Image B31 (lower left)
A Haitian man repairs his tarp shelter after being damaged from a storm.

Image B33 (upper right)
People gather under a tarp shelter in Hati. (Note the roof hole in the UNICEF tarp)

Image B34 (lower right)
Extensive holes in the tarp roof of this woman's shelter located in Georgetown, Guyana.

with a tarp you'll still get wet."[8] Although the Haitian government had requested 200,000 more tents from aid agencies in May 2010, it did not see this response from agencies. Instead humanitarian organizations donated 10,000 rolls of durable plastic sheeting. Each roll is capable of housing 10 people.[9]

The provision of tarps instead of tents was a decision made by NGOs that receive funding from USAID. NGOs were forced to tighten the belt with Haiti relief strategies or be faced with the possibilities of funding cuts from USAID. If humanitarian organizations do not simplify the Haiti relief strategies, they will also be faced with the decision to cut down on staff costs (due to lack of continued funding from USAID). USAID stated that Haiti was diminishing their funds, and it would be difficult to cover the costs of future world disasters.

This news was then circulated around the NGO community. The 'ideal' adequate shelter now came in the form of the less-expensive tarp.[10] Days following this unofficial press release, USAID officials told reporters at Reuters that tents were expensive and impractical, "Haitians are only familiar with the tent as a relief shelter, they will be educated on the benefits of the tarp shelter."[11] It may be a coincidence that humanitarian agencies are showing more interest in tarp shelter solutions following USAID's unofficial report. It was also noted that this strategy was growing in approval among aid organizations outside of USAID's funding bracket.[12]

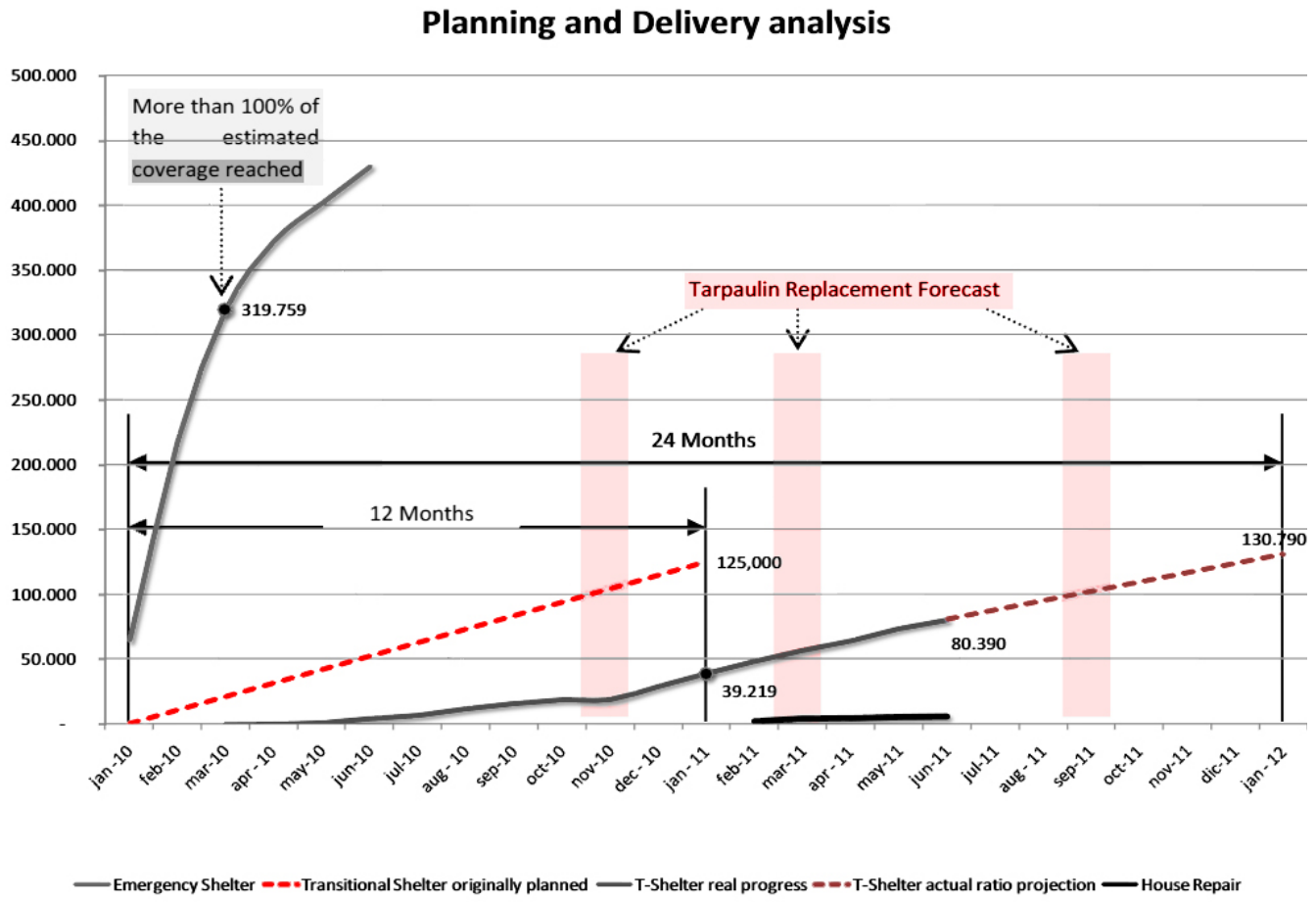



Fig. 2.02

One must point out that aid agencies know that these shelters will fail, and forecast tarp replacement every 4-6 months (Fig. 2.02) for the next two years in Haiti.[13] Most of these agencies did not integrate into their proposed funding expenditures the replacements of tarp material.[14] Many are left baffled that USAID would take credit for a strategy that achieved questionable success and reports surfacing that show the tarps donated by USAID were of very poor quality.[15] Agencies claim that you can stand inside a tarp shelter, and the tarp material will eventually be replaced by timber and corrugated steel.[16] Haitians who received this shelter are concerned whether or not this promise will be fulfilled.[17]

The debate about whether humanitarian organizations should provide tents or tarps depends upon whether ample funding is available for tents. In Haiti following the earthquake of 2010 funding for relief reached unprecedented levels. Humanitarian organizations were still faced with the challenges of budget constraints, and eventually they were forced to downgrade with the tarp shelter. Haiti may be an example of mismanaged funds during relief operations. However, the case has been made clear: when funding is available, the beneficiaries and the receiving governments prefer to be supplied with the tent.


Image B35 (above)
Photograph from Office of Inspector General's Audit of USAID's Efforts to provide Shelter in Haiti. USAID was required to build temporary shelters that lasted 3 years, this tarp exterior failed after 3 months.[18]

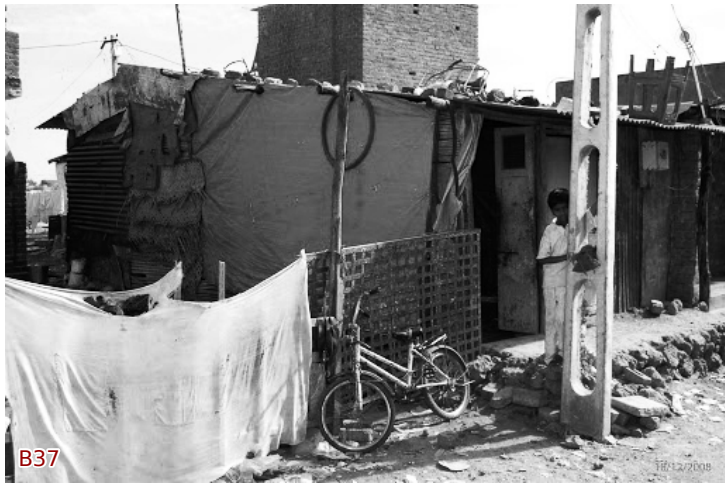
## 80% of Shelter Built After a Disaster

"There is something in the human spirit that will survive and prevail, there is a tiny and brilliant light burning in the heart of man that will not go out no matter how dark the world becomes." - Leo Tolstoy[1]

After a natural disaster the affected people immediately begin in their own aid process. People are simultaneously providing search and rescue help while others are constructing emergency shelter from the rubble scattered across the landscape.[2]

Owner-driven reconstruction (ODR) is the process where people rebuild back by themselves without financial help, technical assistance, or donated materials.[3] This is the most common practice following a disaster and accounts for over 70% of the reconstruction efforts.[4]


Although humanitarian organizations promote how many emergency shelters, they have supplied or how many permanent homes they have built, in reality, these are distributed to a few beneficiaries who were selected among the entire affected population.[5]




Most, if not all shelters are often constructed ad hoc with whatever material is available and assembled fairly quickly. If no directions are given on how to improve shelter strength, people will assemble them with the previous indigenous construction methods.[6]

Image B36 (lower centre)
Example of owner built shelters following the earthquake in Haiti.

Image B37 (above)
Owner built shelter in Noorani Mohalla, Baroda, India.

Improving construction knowledge and techniques will mitigate against unnecessary damage in future disasters.[7]

Owner-driven reconstruction is credited with being the fastest recovery model for the affected country and has the highest satisfaction rate among home owners.[8] There is a need to educate people rebuilding after a disaster highlighting new construction techniques. Theoretically, this will reduce the amount of damage inflicted by the next disaster.[9]


B38

Owner built shelters that are constructed right after a disaster eventually will transition into permanent housing. If eighty percent of shelter built by the affected population after a disaster transitions into reconstructed housing without external technical advice, how will these homes fare in the next disaster? Building back better is the goal humanitarian organizations try to achieve while reconstructing after a disaster, but this can only be achieved within the projects they sponsor. Such projects account for fewer than twenty percent of the complete reconstruction.[10]

Writings about the performance of the owner built shelters is sparse at best. Humanitarian agencies rarely mention indigenous shelter solutions over their own shelter designs for fear of decreases in funding from donors. Owner-driven reconstruction remains a key to a steady and swift rebuilding process. If technical construction advice is not given there will be no building back better, only building back the same.

Section Summary:
Humanitarian agencies offer several types of emergency shelters to those affected by a disaster. None of the shelters currently offered is a 'perfect' solution. Not many of the shelters last beyond a year. Most of the reconstruction is done by the affected population without the help of humanitarian agencies.

In next section:
Section 3 presents information on security concerns within an emergency shelter. Whether emergency shelters address the needs of vulnerable populations. Attempt to show the length of time people may end up living in emergency shelters. Design criteria for emergency shelters and camps. Develops an argument in favour of shelter reuse.

Design considerations:
- shelter must be assembled using low-tech construction techniques in order to utilize regional labour capacity
- materials used for tent making on current market lack durability needed, look at types of fabric from related and unrelated fields


B39

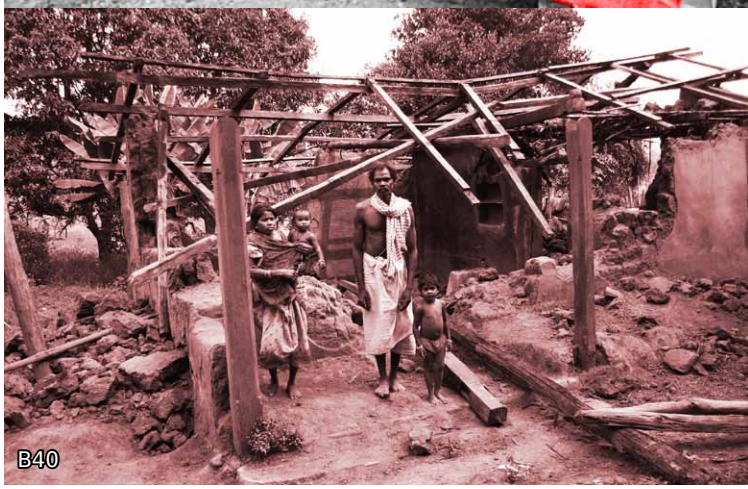

B40

Image B38 (left)
Widows from Myanmar sit inside their makeshift shelter.

Image B39 (upper right)
A Haitian man uses salvaged materials to complete his Catholic Relief Services donated tarp shelter at the Petionville camp.

Image B40 (lower right)
Building begins right after the disaster

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# CONSIDERATION


C01

C03

C02


C04

# Security Assessment

"Since we arrived here, there were armed men taking all the food from us. They have been snatching every little that we get, they also come at night time and threaten us with weapons and threaten us with their weapons and take the little that we have in stock." - Halima Nahar, an IDP[1]

Emergency shelters (agency supplied or owner constructed) are criticized with not providing enough security for their occupants. These shelters do provide protection from ultraviolet rays and precipitation. They do not provide proper protection from thieves. UNHCR uses the term 'emotional security' when describing what a shelter must provide for those who use it.[2] This term has many different meanings. Clearly, the UNHCR is not stating that emergency shelters are secure.

These shelters will not provide protection from theft or prevent violent acts from being committed against its occupants. Women are most in danger from criminal acts and sexual violence committed against them in internally displaced person camps. Within the first 150 days of Haiti's 2010 quake more than 250 cases of rape were reported across several emergency shelter camp sites.[3]

The tent in its present form will not have the capabilities to deter these acts from happening. Zips can be opened, ropes can be untied, and typical skin materials (polyethylene sheets, plastic sheeting, ripstop nylon, etc.) can be cut open with knives easily. Fabric materials may never have the sense of security as robust materials like wood, brick, and steel have.

Some composite manufactured fabrics do have protective qualities. Both Kevlar and Teflon are synthetic fabrics that are ballistic rated. They have the ability to stop some metal projectiles.[4] A 1100 Dtex polyester fabric is resistant to punctures and cutting from sharp objects. It is specified in the

(see page 70 for end notes)

Image C01 (opposite top left)
Haitian National Police and UN Police patrol IDP camp in Petion Ville Club, Haiti.

Image C02 (opposite lower left)
Repairing a tent made from many different tarps in Delmas, Haiti.

Image C03 (opposite top right)
IDP shelters in Mogadishu, Somalia.
(note how easily they can be broken into)

Image C04 (opposite lower right)
Sahara, Sudanese Rebel Group may cause stress to people in IDP camps aligned with other political parties of Sudan.


C05

Image C05 (left)
Haitian National Policeman takes down an IDP tent in Haiti with a knife.

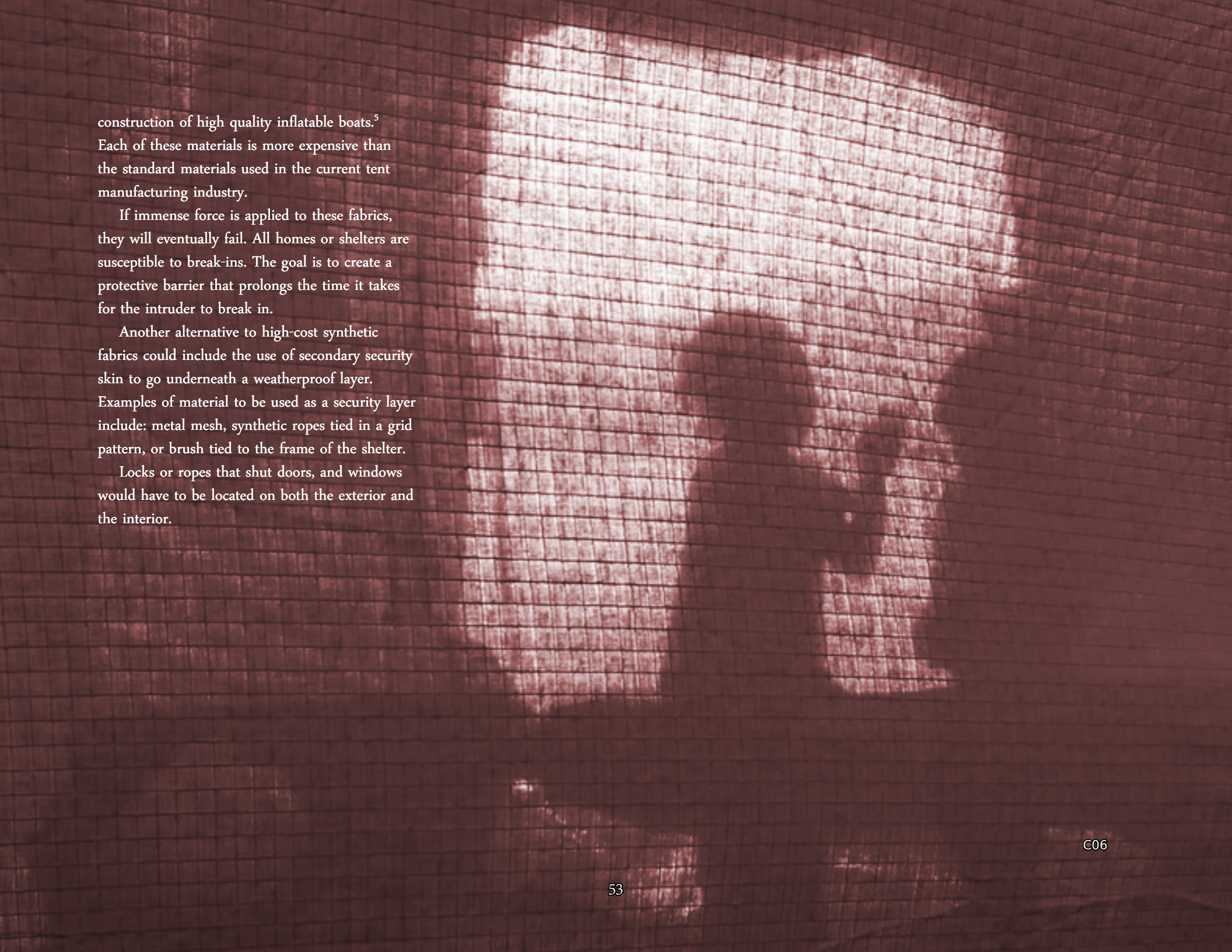
Image C06 (opposite)
Children inside a UNHCR tent in Angree, Abidjan, Côte d'Ivoire. Notice how the thin tent wall shows their silhouette inside.

construction of high quality inflatable boats.[5] Each of these materials is more expensive than the standard materials used in the current tent manufacturing industry.

If immense force is applied to these fabrics, they will eventually fail. All homes or shelters are susceptible to break-ins. The goal is to create a protective barrier that prolongs the time it takes for the intruder to break in.

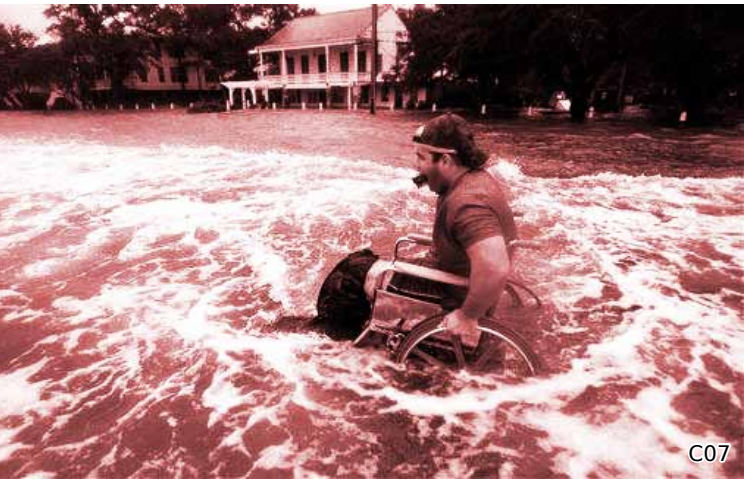
Another alternative to high-cost synthetic fabrics could include the use of secondary security skin to go underneath a weatherproof layer. Examples of material to be used as a security layer include: metal mesh, synthetic ropes tied in a grid pattern, or brush tied to the frame of the shelter.

Locks or ropes that shut doors, and windows would have to be located on both the exterior and the interior.



# Needs of Vulnerable Populations

DFID's Social Exclusion Policy: a process by which certain groups are systematically disadvantaged because they are discriminated against on the basis of their ethnicity, race, religion, sexual orientation, caste, descent, gender, age, disability, HIV status, migrant status or where they live. Discrimination occurs in public institutions, such as the legal system or education and health services, as well as social institutions like the household.[1]


C07

People most affected by disasters are vulnerable populations and include: the elderly, those with disabilities, and children. Some single mothers, unwed or widowed women may be vulnerable as well. They may not have the necessary resources to construct their own shelter or assemble the shelters that humanitarian agencies have donated.

C08

People with disabilities have the greatest difficulty obtaining basic needs such as shelter in comparison to the able person.[2] [3] Sphere Standards do not have satisfactory information addressing how to help those with disabilities following a disaster. World Health Organization estimates that 10% of the world's population has a disability.[4]

In 2005, after Hurricane Katrina 986 of the 1,836 people who died were ages 75 and over. Many were left in old-age homes as their caregivers fled for safety. Often this population group is reluctant to seek the help of strangers and is an easy target for those who wish to take advantage of them.[5]

**Image C07 (left)**
**A disabled man is left to deal with the flood water following Hurricane Katrina.**

**Image C08 (above)**
**A slide at a WHO (World Health Organization) summit showing the number of people who have diasabilities in our world.**

**Image C09 (opposite)**
**A woman builds a shelter at Iffou 2 refugee camp in Dadaab, Kenya.**

C09



Some single mothers, widows with children, and single woman may suffer increasingly harsh circumstances following disaster. If these women were employed before the disaster, that position may be no longer present. Male applicants quickly fill new job opportunities that follow. Single women, single mothers, and children may not have any knowledge about the construction of shelters (dependent on cultural paractices and global location). This is another task that they have in addition to raising children and providing income for the family.[6]

Vulnerable people require adequately constructed shelters the most. The majority this demographic will need assistance to help build their shelter or for others to build it for them. They may not have the technical skills required to make repairs to their shelter if it becomes damaged. New emergency shelter solutions will have to be developed in order to provide these people with shelter. Currently, there are no emergency shelters on the market that can last beyond a one-year time span.[7]

Image C10 (upper left)
Could someone with a disability repair this shelter? Camp Canaan, Haiti.

Image C11 (lower left)
Water is being delivered to Haitians off of a Carrier Air Wing (CVW) 17. Would someone in a wheelchair be capable of competing for aid?

Image C12 (opposite)
Survivors from the extensive flooding in Pakistan take shelter from the rain underneath a piece of foam.

## Shelter Design Criteria and Published Guidelines

The IFRC-OCHA MoU defines emergency shelter as: "The provision of basic and immediate shelter needs necessary to ensure the survival of disaster affected persons, including 'rapid response' solutions such as tents, insulation materials, other temporary emergency shelter solutions, and shelter related non-food items. This definition explicitly excludes transitional and permanent housing."[1]

The guideline most referenced within the relief community regarding shelter (as well as other various subjects) is the *Sphere Project* and was established in 1997. A collection of people from a multitude of charitable organizations (Oxfam, ACT Alliance, CARE International, Caritas Internationalis, The International Federation of Red Cross and Red Crescent Societies, RedR International, Salvation Army, and many more...) helped create a handbook for minimum standards regarding humanitarian operations.[2]


The minimum shelter recommendations are 3.5m² required per person. Camp sizes require 45m² surface area allocated for every person and will include: shelter plots, roads, footpaths, educational facilities, sanitation, firebreaks, administration, water storage, distribution areas, markets and storage, and kitchen gardens. The handbook states that everyone has the right to adequate housing.[3] The criteria used to determine how 3.5m² and 45m² became the standard was not explained in the handbook. The *Sphere Project* does not explain the methods necessary in determining whether a shelter or house is deemed adequate.

The alternative to the *Sphere Project* is called *Compas Qualité (Quality Compas)*. It was created from 1999 to 2004 with the support of numerous NGO organizations, ECHO, the French Ministry of Foreign Affairs (especially the Délégation à l'Action Humanitaire), the Swiss Ministry of Foreign Affairs, the Spanish Ministry of Foreign Affairs and the Fondation de France. This handbook aspires to benefit those who will receive humanitarian aid. While the *Sphere Project* is directed towards standardizing minimum standards for stakeholders to abide, *Quality Compas* is focused on the continuous improvement in quality of services provided to the crisis-affected population through adapting project management and successive project evaluation.[4] The tone indicated

in *Quality Compas's* text shows that it favours the beneficiaries. They warn organizations when seeking funding partnerships and suggest avoiding those that will manipulate or exert pressure on the relief intervention.[5] This handbook reads as more of a supportive text to help guide organizations with implementing their projects.

Most aid organizations have their own minimum standards which they adhere. Reports show a common criticism towards *Sphere* standards indicating they focus too much on the technical aspects of the humanitarian response while ignoring other social responses that contribute to rehabilitation after a disaster.[6]

**Comparison of Sphere standards and UNHCR standards**

| | The Sphere Project 2010 indicators | UNHCR 2007 standards |
|---|---|---|
| **Minimum surface area of camp per person** | 45 $m^2$ including infrastructure | 45 $m^2$ per person recommended (including garden); should not be less than 30 $m^2$ per person (p. 210) |
| **Minimum covered floor area per person** | At least 3.5 $m^2$ except in extreme circumstances (pp. 219–220) | 3.5 $m^2$ in warm climate 4.5–5.5 $m^2$ in cold climate or urban situations, including kitchen and bathing facilities (p. 221) |
| Firebreak | | |
| **Minimum distance between buildings** | Planning guidance of 45 $m^2$ per person including firebreaks (p. 217) | Minimum twice structure height, three to four times structure height if highly flammable (p. 219) |
| **Minimum distance between blocks of clusters of dwellings** | 15 m | 30 m per built-up 300 m (p. 219) |
| Water supply | | |
| **Minimum quantity of water (litres per person per day)** | 15 (p. 63) | 15–20 (p. 549) |
| **People per tap-stand** | Maximum 250 (p. 65) | 1 tap per 200 people not further than 100 m (p. 549) |
| **Distance from dwellings to taps** | Maximum 500 m (p. 63) | Maximum 100 m or a few minutes' walk (p. 219) |

**Fig. 3.01**

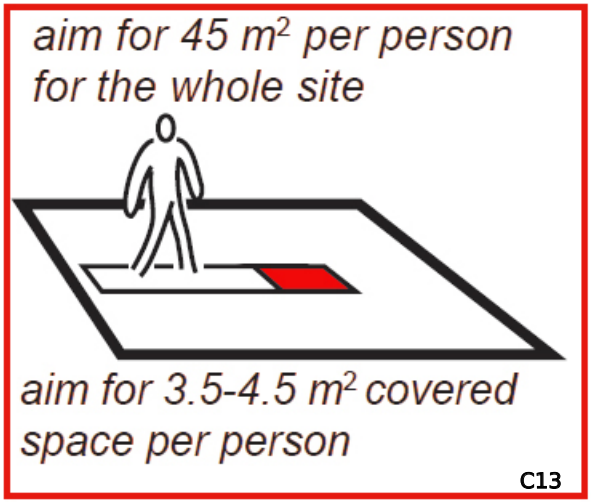
Fig. 3.01 (right & opposite)
Sometimes it is good to draw from a mulitude of standards. Contrasting several standards may help find more 'acceptable' minimums.

Image C13 (opposite upper right)
Visualizing the difference between covered and open space per person in *Sphere Project Standards*.

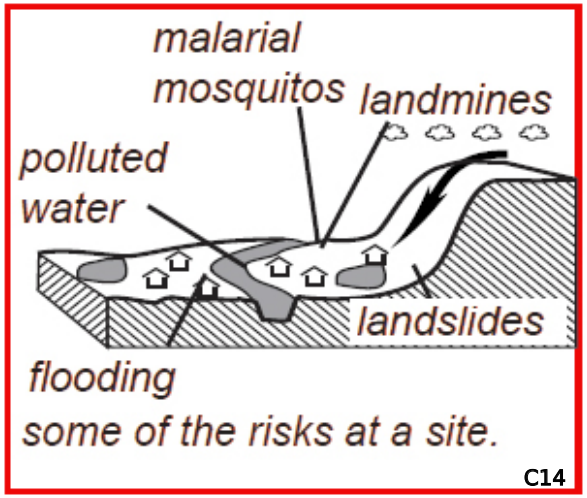
Image C14 (opposite lower right)
*Sphere* standard will attempt to address more than the issues illustrated in this graphic.

| | | |
|---|---|---|
| **Sanitation** | | |
| **Maximum people per latrine** | 20 people (if sex segregated public toilets) (pp. 71–72) | In order of preference: (1) family (5–10 people) (2) 20 people (p. 549) |
| **Distance from dwelling to toilet** | Maximum 50 m (p. 71) | 6–50 m (p. 549) |
| **Minimum distance between latrines and soakaways and ground-water source** | 30 m (p. 74) | 30 m (p. 269) |
| **Distance from bottom of pit to water table** | Minimum 1.5 m (p. 74) | Minimum 1.5 m (p. 269) |
| **Refuse** | | |
| **Distance from dwellings to refuse disposal** | Less than 100 m to communal pit (p. 83) | |
| **People per 100-litre refuse container** | | 50 (p. 549) |
| **People per 2m x 5m x 2m communal refuse pit** | Maximum 10 families (p. 83) | 500 (p. 549) |

Fig. 3.01 cont.




C13



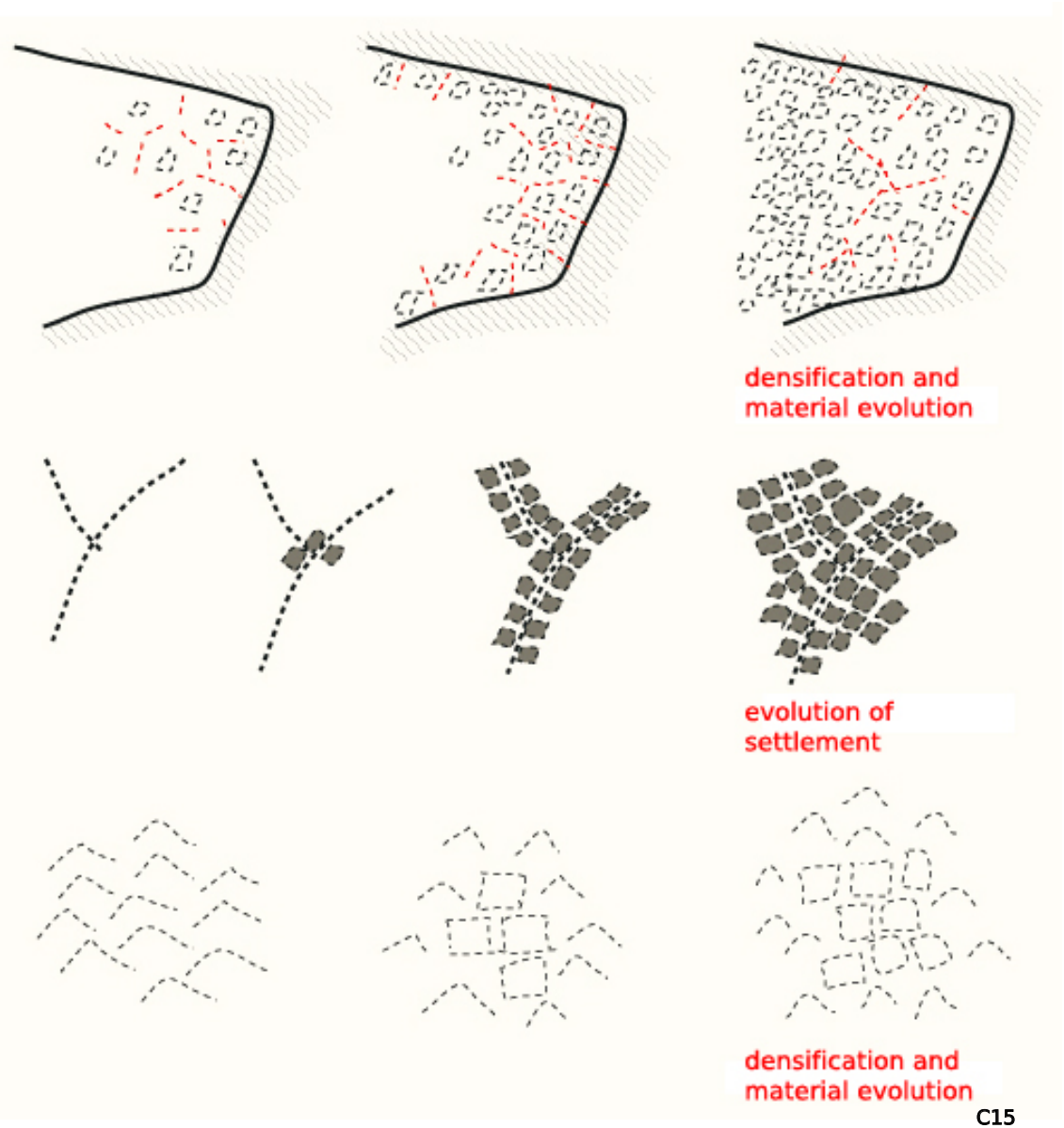

C14

# Settlement Patterns and Camp Planning

Camp placement after a disaster is primarily done by the affected population. Camp settelment is done before the international community has established itself. As NGOs arrive, they determine which location would best to situate an IDP (Internally Displaced Person) site. Meanwhile, the majority of the population has already decided on their site locations. One year after the earthquake in Haiti it was observed that 80% of IDP settlements were informal (Image C15).[1] People have a tendency to locate themselves near their destroyed homes, community, or family.

If the affected community cannot build emergency shelters as infill between the rubble they will relocate somewhere nearby as a whole community and maintain social relationships.[2] These solutions are defined by UNHCR (United Nations High Commissioner of Refugees) as dispersed settlements and self-settled camps.[3]

While informal settlements and infill shelters near damaged homes are preferred by the population after a disaster they do have several problems. Sanitation becomes the primary concern for these settlements, as well as proximity to water, food, and medical distribution. These camps may also be considered non-recognized camps (which decreases their ability to receive aid)



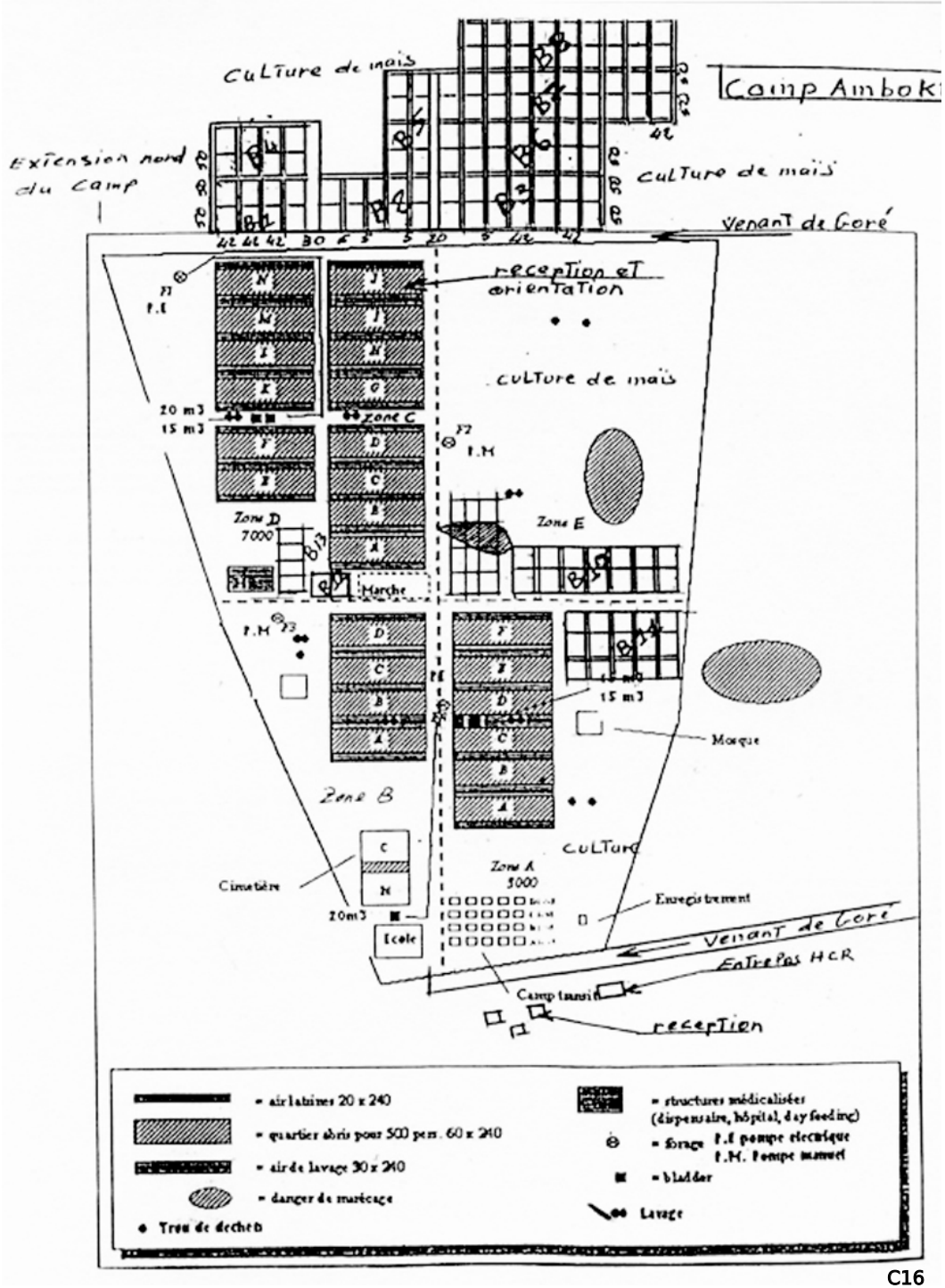

C15

not deemed legitimate by national authorities. People located within these camps often operate independently of aid or are not eligible due to their small sizes, location on hazardous or private land, lack of access (damaged roadways), and security concerns.[4]

When camps are planned by humanitarian agencies, they will fall under the category of communal shelter centres, transit camps, or planned camps. Mass shelter collective centres provided accommodation in pre-existing large buildings like schools, warehouses, barracks, gymnasiums, community centres, etc. Mass shelter is intended to be an extremely short-term solution. Transit camps are intended to be very temporary as well. They provide accommodation until semi-permanent solution replaces it. The planned camp is provided by the government or donor agencies and has all the infrastructure needed to sustain life there in such as water, food and non-food items, education, and health care. This option will require the most amount of time and resources in comparison to all other options.[5]

The bare minimum is 30m² per person in camp planning. This does not include garden space, which would bring it up to 45m². Roads, foot paths, educational facilities, sanitation, security, firebreaks, administration, should be included within the 30m² required per person.

Image C16 (right)
UNHCR Plan of refugee camp in Amboko, Chad.




C16

water storage, distribution, markets, relief item storage and distribution, and plots for shelter. This will not include areas for agriculture or livestock, as well as areas for outdoor recreation.

Sites that have 2-4% slopes are most preferred, as 1% site slope will not drain water quickly and slopes over 10% need costly site preparations. One latrine per family is the ultimate goal, where this cannot be achieved a maximum of 20 people per latrine is an acceptable and 50 people latrine is permissible for very short durations. They must be located 30 metres from ground water or water sources and no more then 50 metres from shelters. Water distribution points should be located no further than 100 meters from any shelter. A firebreak is recommended every 300m of built up area and should be no less than 30m wide.

Other infrastructure amenities include: 1 water tap per 1 community (80-100 persons), 1 latrine per 1 family (6 - 10 persons), 1 health centre per 1 site (20,000 persons), 1 referral per 10 sites (200,000 persons) hospital, 1 school block per 1 sector (5,000 persons), 4 distributions per 1 site (20,000 persons) points, 1 market per 1 site (20,000 persons), 1 feeding centre per 1 site (20,000 persons), 2 refuse drums per 1 community (80 - 100 persons).[6] All of these factors and criteria should be taken into consideration at the beginning of every camp to be designed.

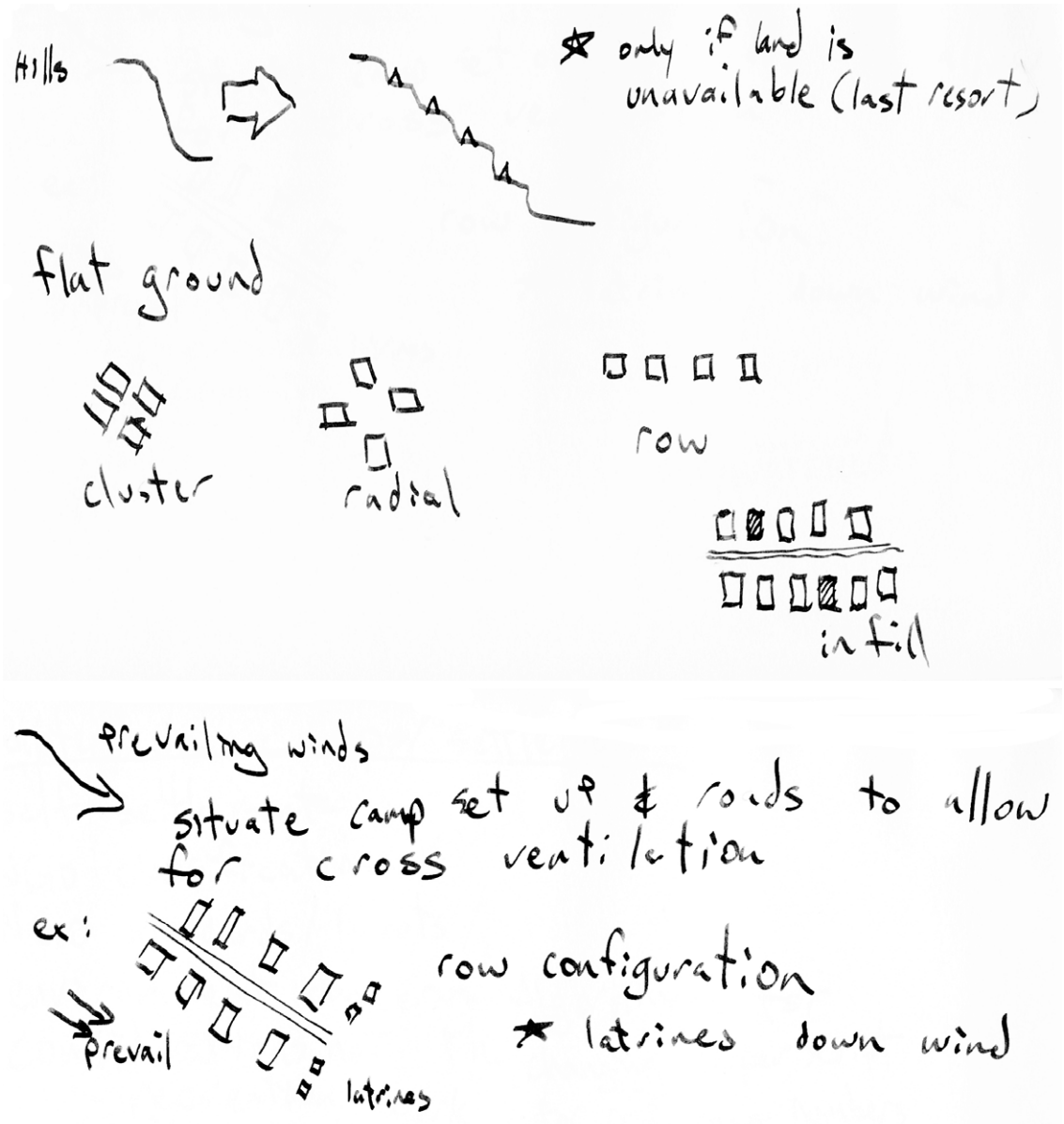



Image C17 (right)
Illustrations showing various camp arrangements.

**C17**

# Universal and Single Solution Designs

"But a man has no more to do with the style of architecture of his house than a tortoise with that of its shell..." -Henry David Thoreau[1]

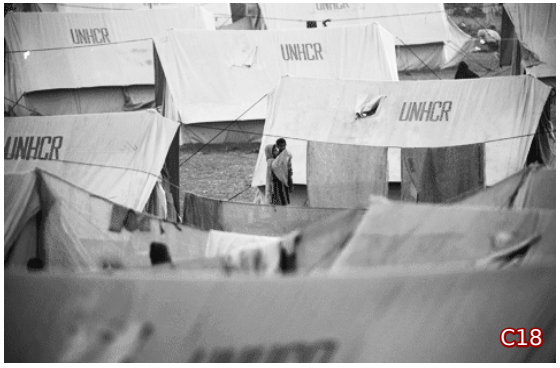
During the last five decades there has been a lot of debate regarding shelter design within the humanitarian community. Some NGO's advocate a distinctive solution for each disaster utilizing geographical materials,[2] while others claim that single use designs complicate the disaster response and delay the reconstruction process.[3] Roger Zetter (Emeritus Professor of Refugee Studies, Oxford University) argues that there is not enough information within the humanitarian sector to discern which approach is more beneficial. He states that there are no studies comparing the impacts of differing approaches to shelter.[4]

Prefabricated shelters or universally designed emergency shelters have numerous benefits, including: lowered design costs, shorter implementation times, and easy construction inspection.[5] [6] While individual solution shelters are designed with local materials and constructed with a regional workforce, they are also more likely to be accepted by the local population.

The US Agency for International Development Office of Inspector General's audit on USAID's effort to provide shelter in Haiti found that USAID was off track for meeting its shelter goals. Variations in the shelter types supplied to those in need was one of the reasons. Furthermore, USAID did not distribute or request standardized shelter design from the agencies that benefit from their funding.

The audit also stated the shelters supplied were supposed to last three years. They observed that the shelters were made with plastic sheeting that was too thin and people could be seen within them during the night. The exterior skin had begun to wear after only a few months. The Inspector General reported these shelters were inadequate and were not likely to last the three year period stipulated.[7]

Should humanitarian agencies provide culturally acceptable designs that utilize local building materials as a single-solution shelter or will more priority be placed on developing quality semi-global solutions?





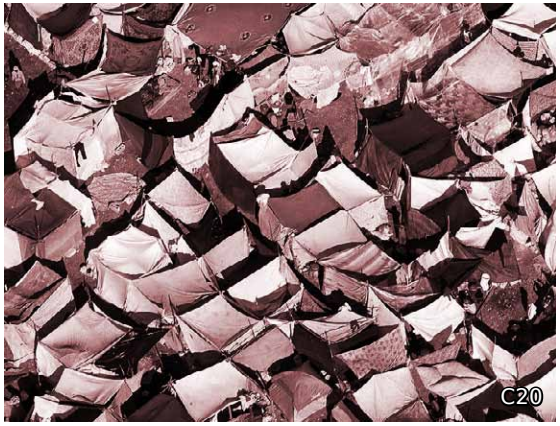



Image C18 (top centre)
Shelters utilizing one design are prevailent amongst humanitarian agencies as a universal shelter response. (after Pakistan floods)

Image C19 (centre)
Owner built shelters may not be the best shelter solution during the emergency phase... (Mogadishu, Somalia)

Image C20 (bottom centre)
...sometimes there are no building materials to make shelter. (Haiti, after the quake)

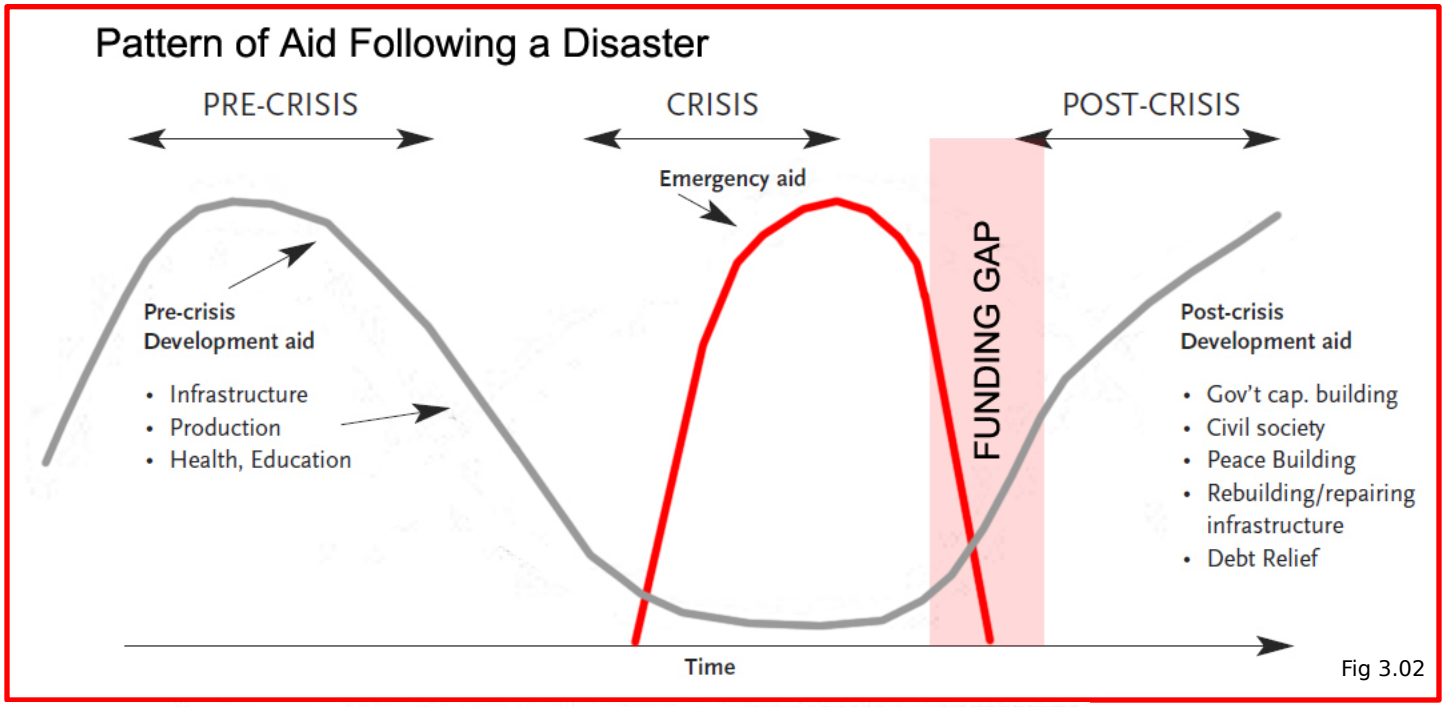



Fig 3.02

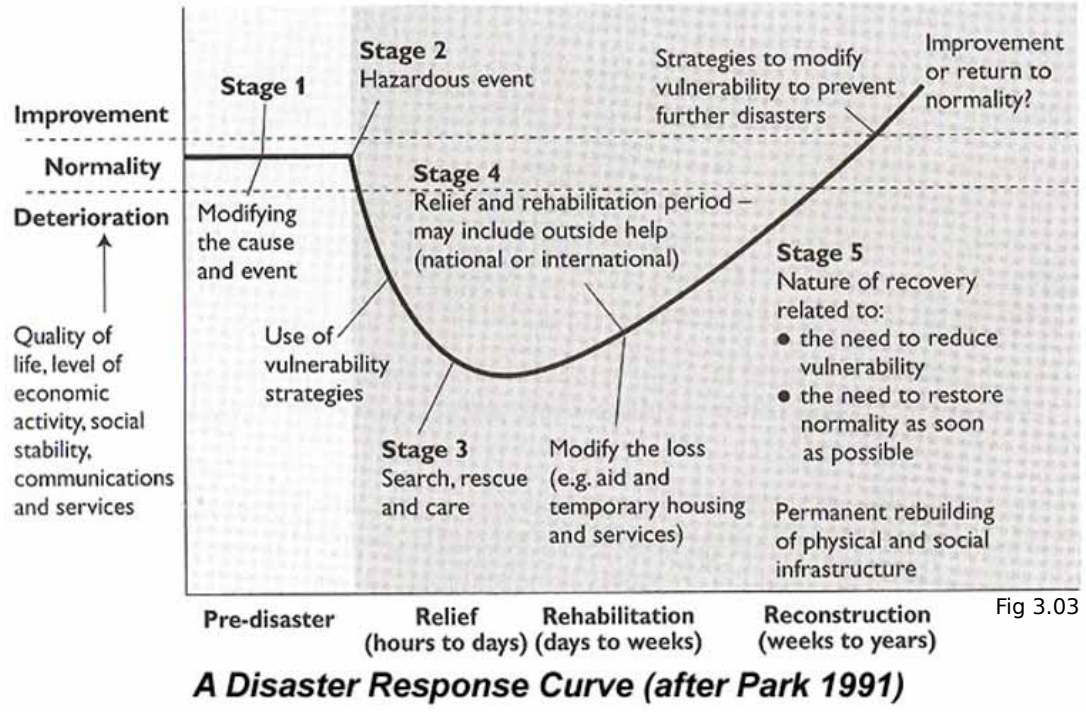



Fig 3.03

Fig. 3.02 (top)
Typical pattern of funding to developing countries after a disaster.

Fig. 3.03 (bottom)
Disaster response timeline highlighting various activities throughout the recovery process.

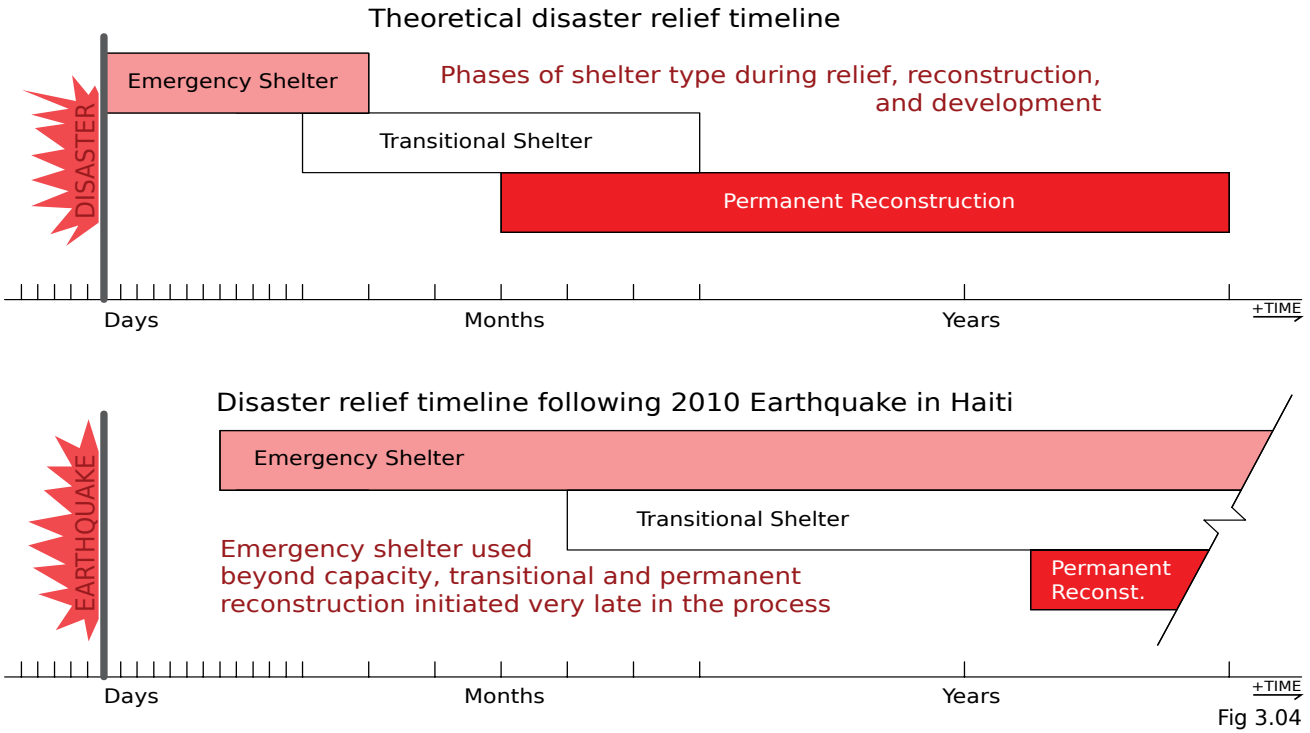


Fig 3.04

## Between Relief and Development

In addition, new skills are needed to work with the very poor communities who are worst affected by disasters, or with the agencies and intermediaries who are engaged with them. Major disasters hit poor communities hardest, both in terms of numbers immediately affected, and through prolonged suffering during reconstruction.[1]

Fig. 3.04 (top)
Theoretical disaster relief timeline vs the current relief timeline being experienced in Haiti. Every disaster relief timeline is different. Some recoveries may look similar to the theoretical timeline, while others have complex issues that prolong the development process.

A funding gap is typically defined as the difference between the amount of money available and the amount of money needed.[2] Immediately following a disaster the UN Central Emergency Response Fund (CERF) releases money, which will be used for the relief effort. These funds are only for immediate use, and CERF is grossly under funded.[3] Funding raised for disaster relief comes from various sources and will always go through a pattern of peaks and troughs.[4]

However, there is a common pattern with how aid agencies release funding after a disaster. An initial release of funds will be allocated to immediate disaster responses such as: search and rescue, water and food aid, and medical supplies. If the budget allows it, then tents, tarps, or tools to repair shelters will be purchased for distribution. Plans must be made very early on to include transitional shelters or semi-permanent housing within the budget. If agencies underestimate the need for this shelter typology, funding will not be accessible when demand arises. There will be shelter shortcomings until reconstruction funds (development aid) are released.[5] This was experienced during the recovery effort following the 2004 Indian Ocean tsunami.[6]

Humanitarian organizations recognize this will be the time period where funding gaps commonly occur in the recovery strategy.[7] Numerous organizations have written articles and documents

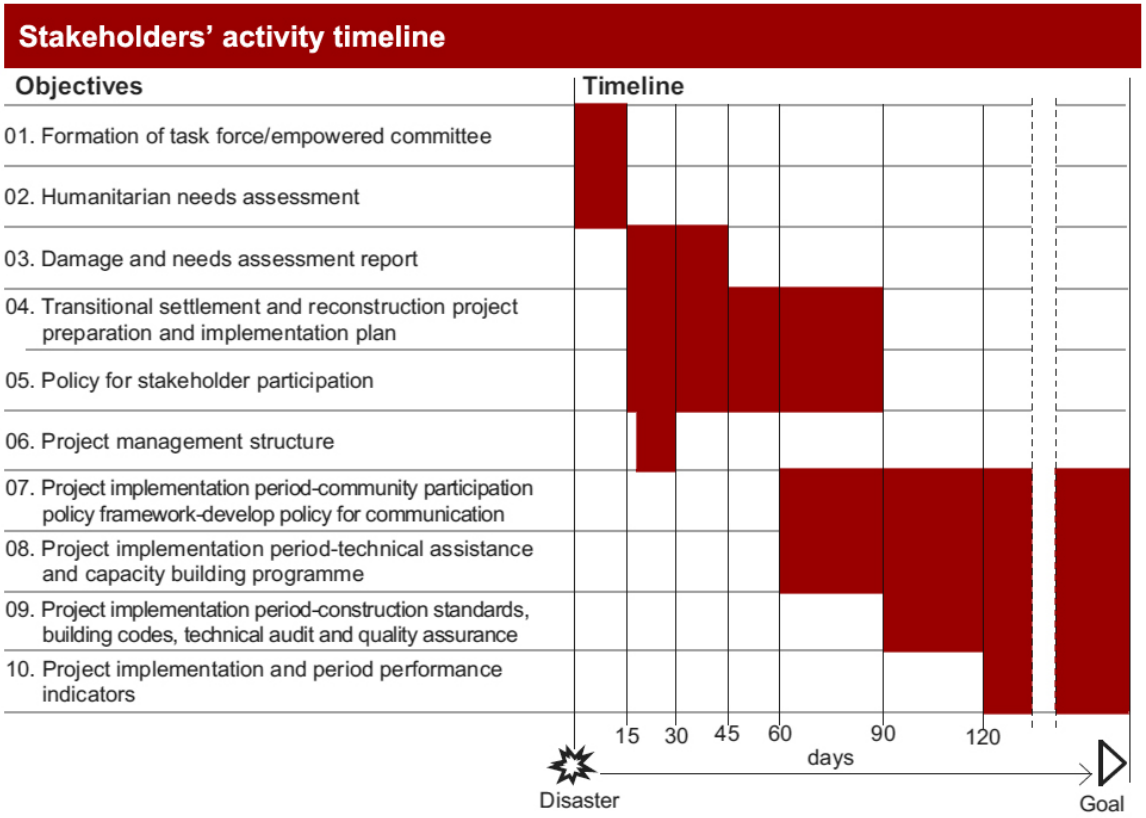



Fig. 3.05

demonstrating how funding gaps can be overcome.[8] [9] [10] Although there may be many funding avenues or financial tools available, funding gaps are typical and reoccurring.[11] [12] Funding gaps will occur with almost every disaster response.

It is extremely hard to predict what the situation will be in the region immediately following a disaster. Preliminary budgets may not have considered problems within the affected environment. Emergency time lines do not follow a predictable linear manner from relief to recovery, and natural disasters complicate pre-existing humanitarian situations.[13] It is not surprising that disaster-relief budget forecasts have shortfalls, and initial projects have budget overruns due to unpredictable complications.

"The transition funding gap expresses the fact, often experienced in post crisis situations, that transition needs receive far less support than required."[14]

Several forms of gaps will pose setbacks during relief and reconstruction following a disaster. The funding gap, planning gap, implementation gap, and participation gaps may be experienced at one time or another during the recovery process. Poor planning can lead to wasted resources, especially if several relief strategies are implemented and pursued in tandem. It would be beneficial if agencies coordinated a strategy together and following it through. Implementation gaps occur when the agency's role has been completed and leave the affected region without passing on information of the work their group had completed. Sometimes this leads to agencies doing the exact same work that the previous agency had just completed. This in return leads to resources being wasted on work being redone.

The participatory gap will affect relief and reconstruction the most. This refers to the capacity and participation of the local inhabitants involved with the reconstruction process. It may take some time for locals to cope with shock and trauma after a disaster. This population is the most important contributor to the reconstruction process. The time it takes for them to reach optimum output capacity may be upwards of a year.[15]

The unfortunate side effects of funding gaps are that beneficiaries of emergency shelter often are not provided with shelter that will last the length of time needed until reconstruction is completed. This time period could be anywhere from two to five years and tents last rarely more than a year.[16]

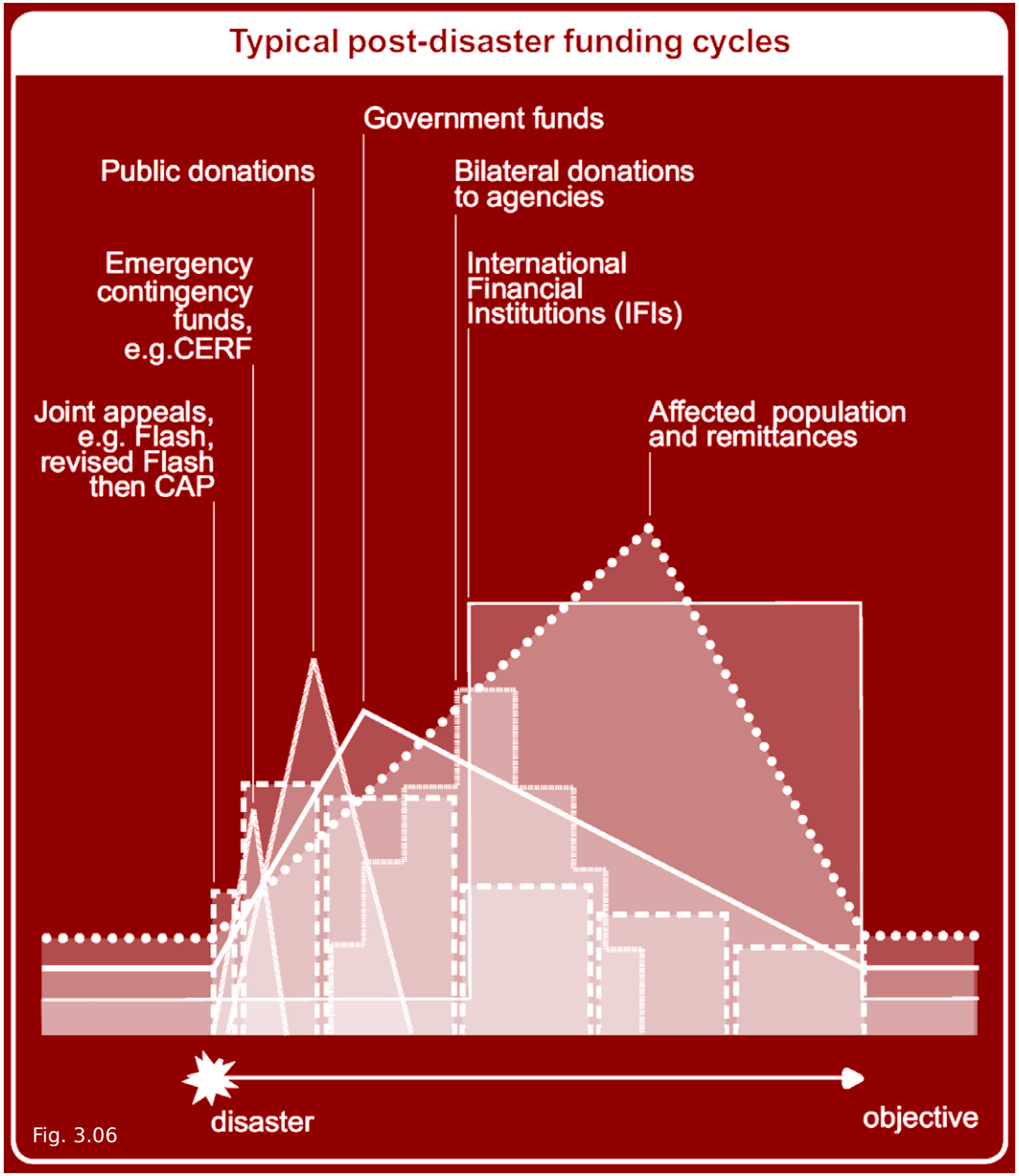



Fig. 3.06

Many agencies forecast expenditures that do not include funds for repairing shelters or replacing tarps that will be damaged during this wait time.

In July 2011, the people of Pakistan were still living in tents due to the destruction cause from the flooding in 2010. This event displaced more people than the 2004 Indian Ocean tsunami, and the 2010 Haiti earthquake combined. For those affected by the flooding in Pakistan, agencies have currently only pledged to build back 17.4% of 825,000 homes destroyed. Extreme damage to infrastructure has hindered the construction effort. This will force many people to continue to live in substandard shelter conditions longer than anticipated.[17]

While looking at the relief process, the overwhelming public opinions assume that funding for relief efforts are spread out over the entire duration of relief through reconstruction. This happens rarely as typical funding patterns of the relief funding show that most of the donation dollars are received within the first phase of relief response. Improper management of funds in the initial phase while financial resources are still high often leads to shortfalls when the time comes for a more permanent shelter solution to be

Fig. 3.05 (opposite)
The theoretical timeline for the disaster recovery process. Although routines are identical each disaster, timelines will not be.

Fig. 3.06 (left)
Overestimated funding cycles after a disaster, many times aid is not released as evenly.

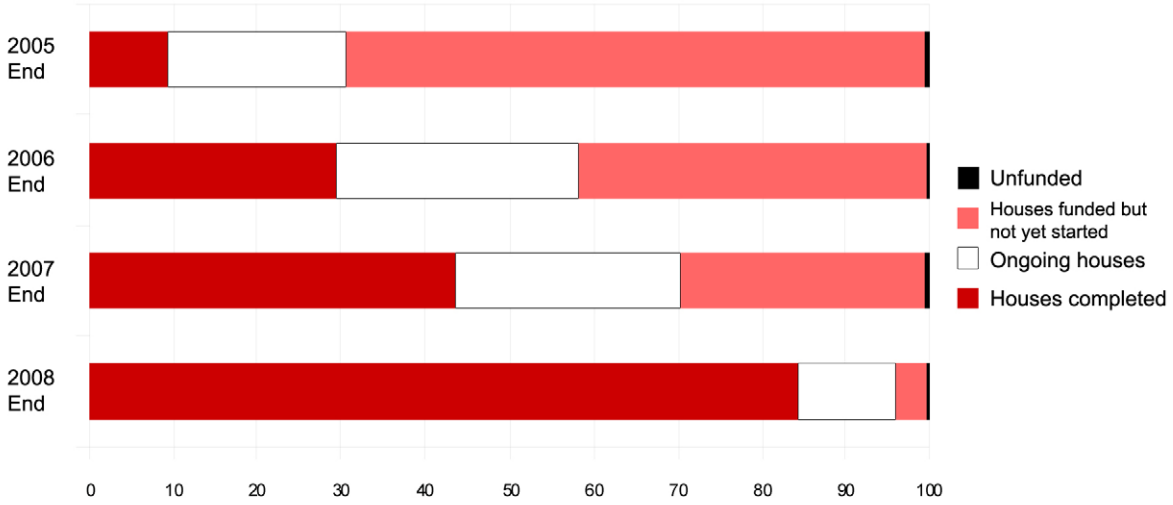



Fig. 3.07

Maldives - Housing progress - percentage of repairs & reconstruction completed

implemented. Some agencies are even forced to withdraw before reaching the reconstruction phase of recovery.[18]

In a report by Sisira Jayasuriya and Peter McCawley on lessons learned from the 2004 India Ocean tsunami recovery plan, they had this to say about funding gaps: It needs to be remembered that cost increases are inevitable. They need to be expected and budgeted when estimating funding requirements for construction programs. Unless this is done, funding gaps will emerge. Indeed, it is surprising that the international disaster management industry apparently did not anticipate this situation in the wake of the Asian tsunami in December 2004.[19]

Fig. 3.07 (above)
The 4 year long process of reconstruction in the Maldives following the 2004 Indian Ocean Tsunami. Even after 4 years, 15% of the homes for the affected population were not competed yet.

## The Case for Reuse

"The good Earth—we could have saved it, but we were too damn cheap and lazy." - Kurt Vonnegut[1]

Although humanitarian agencies currently support tarp shelters as the staple in emergency shelters, a case could be made for durable emergency shelters and should not be disregarded due to higher costs. To a great extent, temporary shelters are appealing to donor agencies due to their quick assembly, light weight (which reduces logistics cost), and they are inexpensive. Tarp shelters can reach the maximum number of people in need. Plastic sheeting used with these shelters must be replaced every 3 – 6 months. The replacement of this sheeting will incur an extra cost in logistics, distribution, and disposal.

Robust shelters that can be occupied for long durations and have been designed for reuse are worth investigating for potential use in relief operations. These shelters would have a high initial cost compared to other shelter solutions. Reuse of the shelter could justify such costs.

There will be several costs affiliated with reuse and should be considered while deciding upon a reusable shelter option, such as: repair, cleaning, transportation, and storage.

After use, the shelter must be inspected for need of repair. The repair process could be minor to major, and the cost range will vary for work needed. This extra work would actually benefit the local economy by providing jobs for people to dismantle and repair shelters.

Shelters must be cleaned with ammonia, diluted bleach, anti-bacterial soap, or another cleaning agents with comparable disinfecting properties in order to kill bacteria. Costs are associated with the use of cleaning solutions, and tools will be needed to be purchased so the solution can be applied. Cleaning emergency shelters will create jobs within the local economy.

After the shelters have been dismantled, repaired, and cleaned, they will need to be transported to a storage facility. Costs associated with transportation will vary greatly between each disaster location. It is unknown which vehicle will transport the shelter or whether ISO containers are available. If logistics companies within the region could be contracted for the transportation services,

this would benefit the local economy.

The shelters must be stored. It is unclear whether warehouse facilities will be available. Some of the larger structures left behind by humanitarian organizations (field hospitals, etc.) could be used to store the reusable relief shelters. If proper warehouse space is unavailable, it must be constructed. A warehouse construction project benefits the local economy by employing regional tradespeople. A relief warehouse would be a wise investment for disaster preparedness. These shelters could also be loaned out to other countries that may be experiencing a housing crisis.

Countries that are prone to reoccurring natural disasters will reap the most benefits from reusing emergency shelters. For instance, Indonesia is in constant danger from earthquakes, tsunamis, and tropical storms. India, Pakistan, and Bangladesh often experience flooding, tropical storms, earthquakes, and tsunamis. Landslides, flooding, and tropical storms are common to countries within Central America. Iran is burdened with a very active fault line. Japan, North and South American are in a zone of our world called 'Pacific Ring of Fire'. Having an enough reusable shelters could safeguard against donor supplied shortages for countries that are more disaster prone. These shelter solutions will increase in supply if money is contributed toward that program annually.

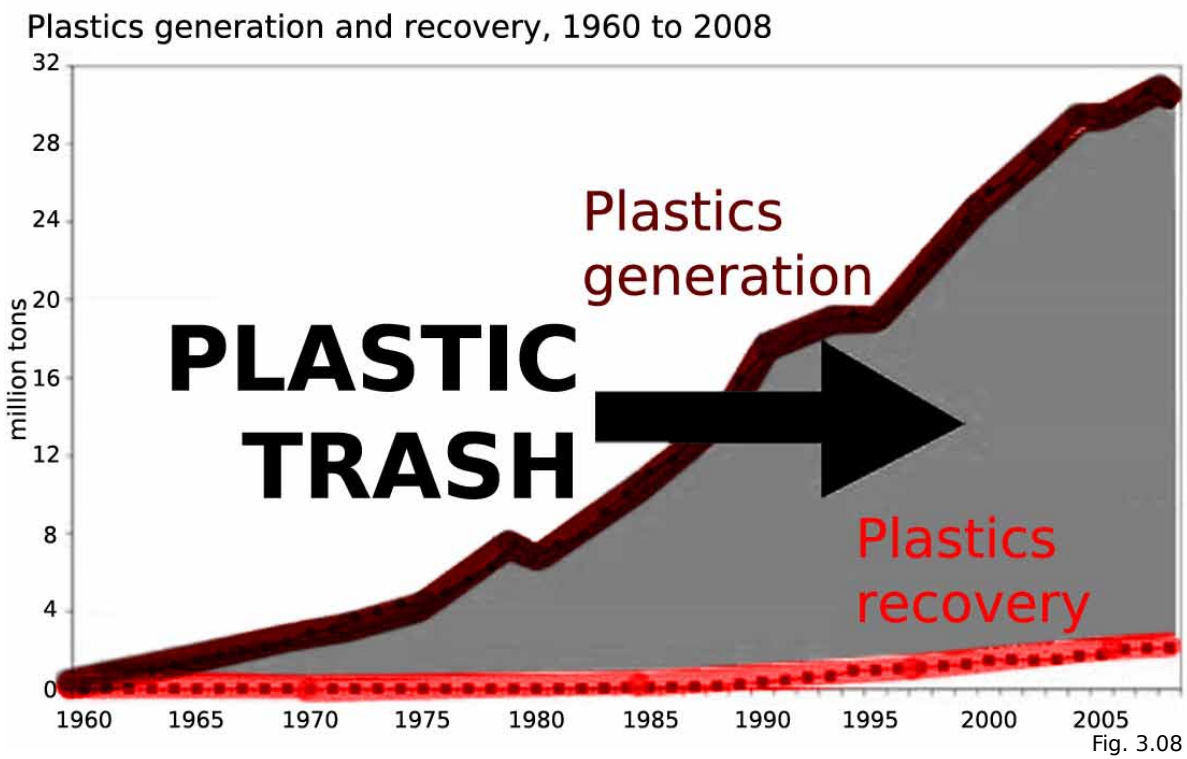


Fig. 3.08

Fig. 3.08 (top right)
The enormous waste of plastics compared to its reuse or recycling.

Reuse also has very positive impacts on our environment. The carbon footprint of a reusable shelter system might be less in comparison to a one-time use shelter.

Humanitarian agencies care about how relief operations will impact the environmental impact within the affected region. The office for the Coordination of Humanitarian Affairs (OCHA) advocates the reuse of material whenever possible during disaster relief missions.[2]

At present, no papers exist on the reuse of emergency shelters, and it is unknown if the process is currently in place, being proposed, or under development.

Section Summary:
Shelters must be made robust enough to limit unwanted intrusions and increase longevity. Increased durability will minimize repairs needed. Some people can spend over 2 years in an emergency shelter while waiting for a new home. 18m² is the minimum size of emergency shelter according to Sphere Standards.

In next section:
Material types will be explained more thoroughly in the next section. Detail is given on how shape can affect strength and how this can influence tent design. A summary of current transportation modes available for relief transportation. Also, a detailed account of components needed for shelter assembly is expanded upon.

Design considerations:
- increase security within light-weight shelters
- alternative materials that add security should be considered if skin cannot accomplish this goal on its own
- size must be >18m²
- shelter should be reusable
- to eliminate wasted time in the field, shelter could be a single solution design

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# ELEMENTS

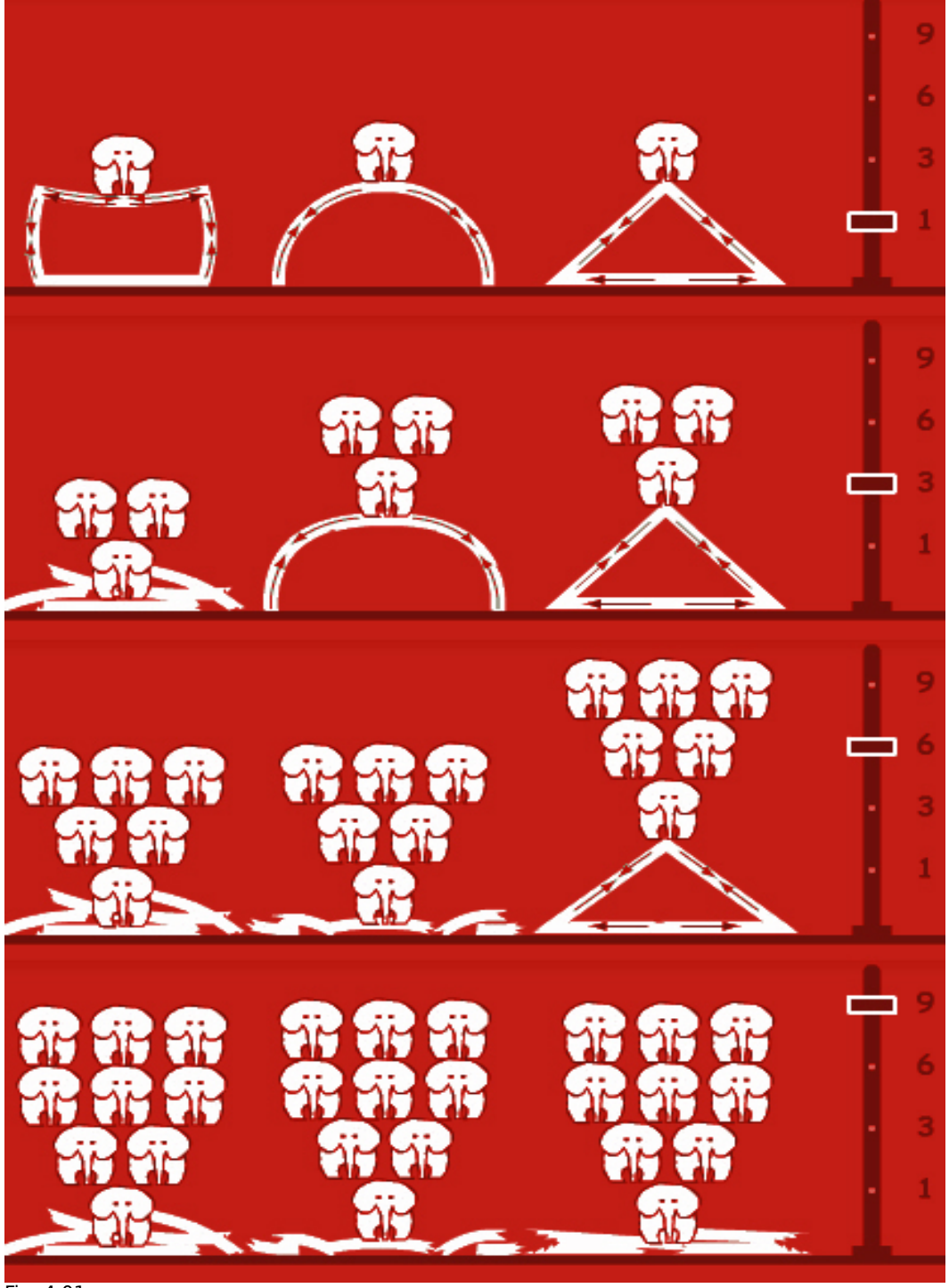



Fig. 4.01

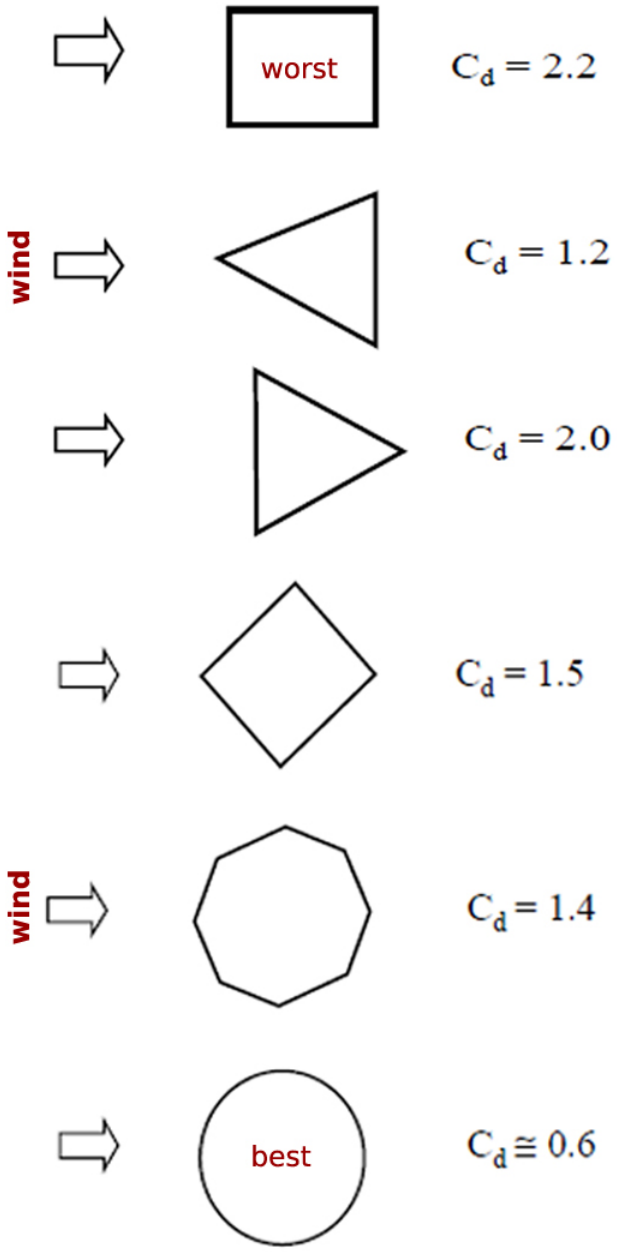



Fig. 4.02

# Strength or Efficiency?

"There is hardly anything in the world that someone cannot make a little worse and sell a little cheaper, and the people who consider price only are this man's lawful prey. It's unwise to pay too little." - John Ruskin[1]

Our world is comprised of four shapes: circle, triangle, square, and the rest fall into polygons (octagons, etc.). The circle includes domes, spheres, and arches in the built world. Triangles will create pyramids and will take on any other shape utilizing triangular geodesic geometry (example Buckminster Fuller's popular domes). The square/cube is one of the most familiar building shapes in our designed environment used for everything from big-box stores to skyscrapers. Polygons are not a conventional shape for our built environment. Some designers have used this shape to create iconic architecture. Polygons are also capable of creating strong complex building systems similar to triangular geodesic geometry. Polygon geodesic geometry resembles the shape of a honey comb. There is one more shape that deserves mention, this is a plane. Planes are generally constructed as walls or skins of a structural component and soil retention walls. Planes will be used as necessary to complete any of the building shapes mentioned above.

When a point load is placed on top of these shapes, the triangle/pyramid is the strongest, followed by the arch and dome, and lastly the square/cube.[2] Emergency relief structures will not need to possess any load-bearing capacity as they are never more than a single storey, and the dominant force applied will be wind loads. Domes perform better than triangles or rectangles in high wind scenarios.[3] The closest thing to a circular dome is the geodesic dome. It also performs well.[4] The pyramid performs adequately under wind loads, and a gable roof will perform the worst out of the triangular-shaped roofs. The square/rectangle building performs poorly in high wind conditions.[5] Squares, cubes, and rectangles are easiest to adapt for expansionand upgrades.

(see page 86 for end notes)

Fig. 4.01 (opposite left)
How building shapes will determine load capabilities.

Fig. 4.02 (opposite right)
Wind load drag values on different building shapes from rectangular to circular. As shapes become more round, less wind drag occurs.

Pyramids and dome structures are not very effective when it comes to expansion or adaptation. If head room is an important design requirement, the dome is best. Triangle-shaped buildings (or shelters with triangular roofs) would be in the middle of this category. Square/cube buildings would be the least efficient due to the excessive amounts of material required to extend shelter height. Shelters with a square/rectangular footprints can easily divide space and create room partitions. Circular footprints do not divide up well.

One important aspect to consider during the design process is how the shape selected will affect manufacturing (waste produced) and transportation (shipment size). The square/rectangular shape will produce the least amount of waste during the production of the skin and will fold in a very compressed manner for delivery purposes. Shelters with triangular roofs are also quite efficient and fold well for shipping. There will be some waste generated during the manufacturing both triangular roofs (on the front and back walls) and pyramid shapes (all four sides will generate waste). The dome and geodesic dome shelter will generate the most amount of waste. This may increase shelter costs due to non-reusable waste. The dome skin will not fold uniformly, this will increase the space required for transportation.

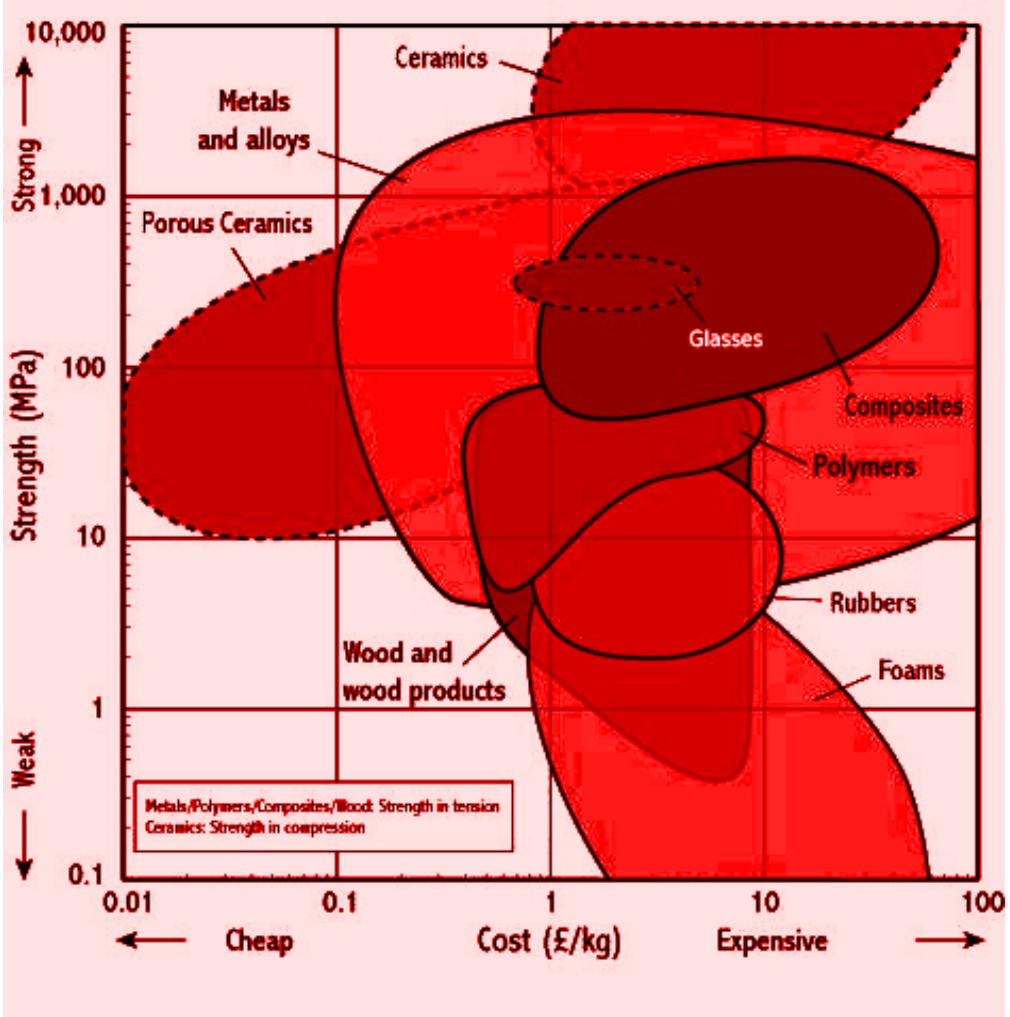



Fig. 4.03

Fig. 4.03 - 4.10
Graphs that show comparisons of numerous attritbutes for a variety of different materials. (Source: University of Cambridge, Department of Engineering)

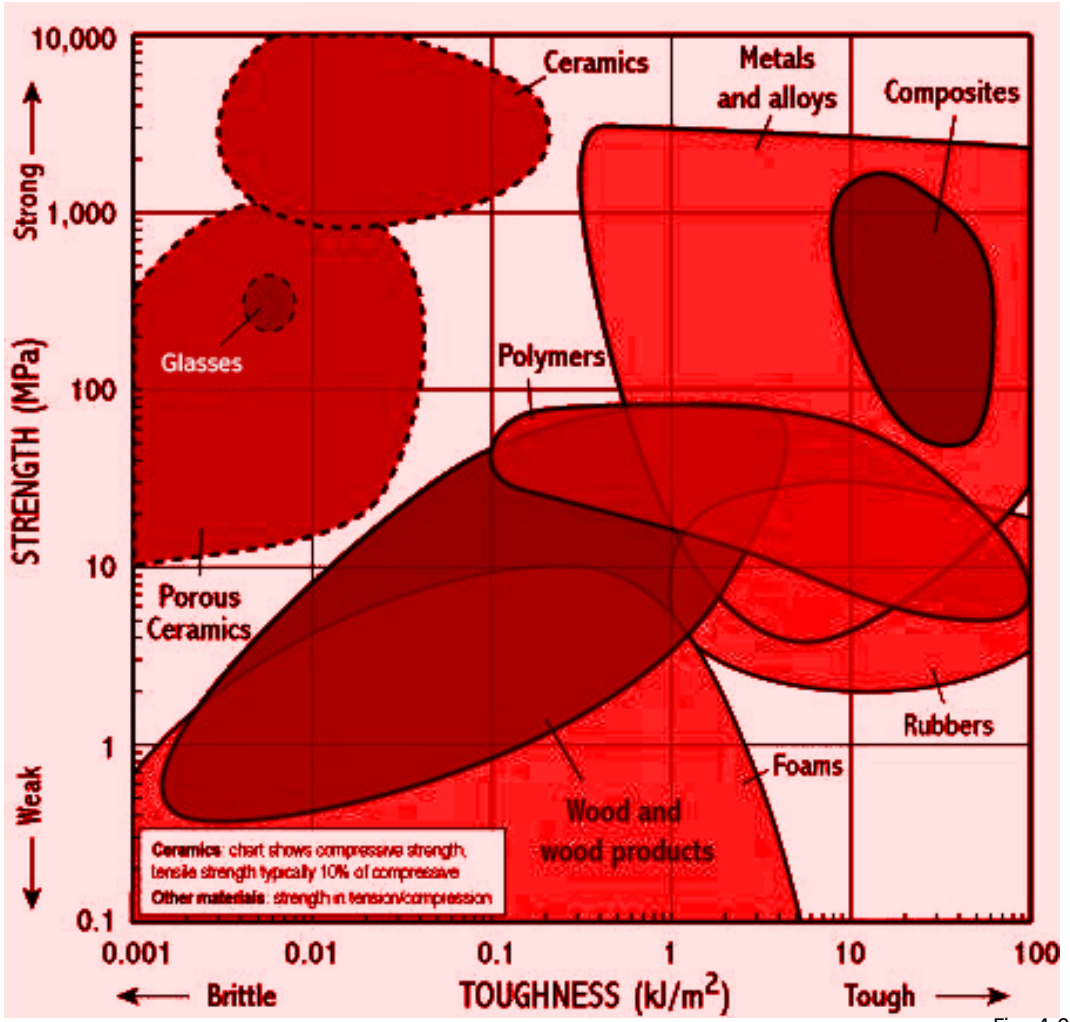



Fig. 4.04

Fig. 4.03 (opposite)
Material cost comparison.

Fig. 4.04 (above)
Visualizing strengths of materials.

# Material Optimization

Material selection is critical when making design proposals for emergency shelter and semi-permanent shelter after a disaster. Selecting which materials should be used and how they may be used can affect the durability of the structure. There may be logistics costs associated when importing the materials needed to complete certain aspects for the shelter design.

Semi-permanent structures (transitional shelters) should be made from more robust building materials whenever possible. Humanitarian organizations will favour materials selected from what is available within the affected country.[1]

Only a few select materials are attainable for the construction of emergency shelter. Emergency shelter accompanies the initial supplies to be transported to an area directly after a disaster. Tents, tarps, and shelter kits will be the first emergency shelter materials to be shipped due to their light-weight characteristics.[2] These shelters will be under the weight constraints imposed by air freight.

Wood and steel building materials will not arrive at a country within three months following the disaster. Typically, these will arrive by sea, unless the affected country has an ample supply of

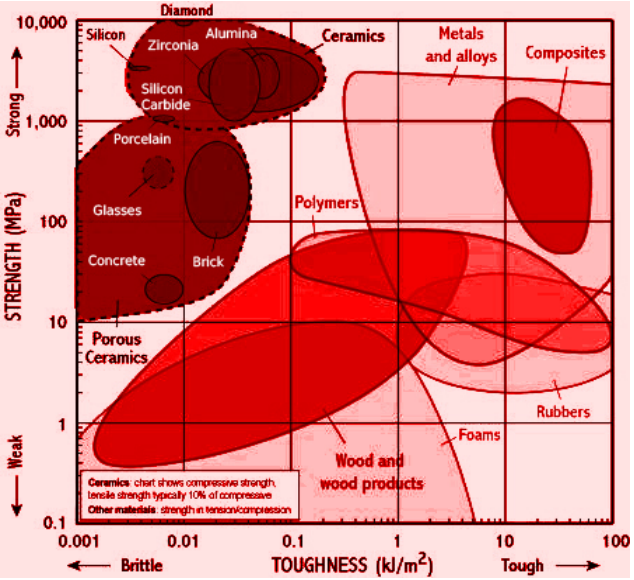



Fig. 4.05

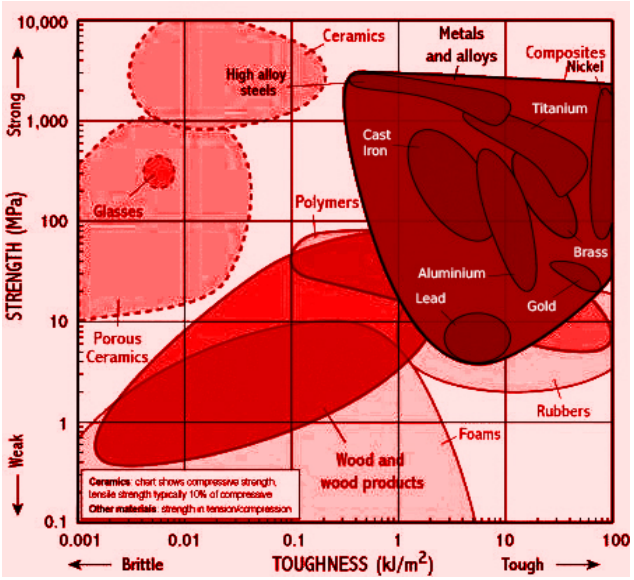



Fig. 4.06

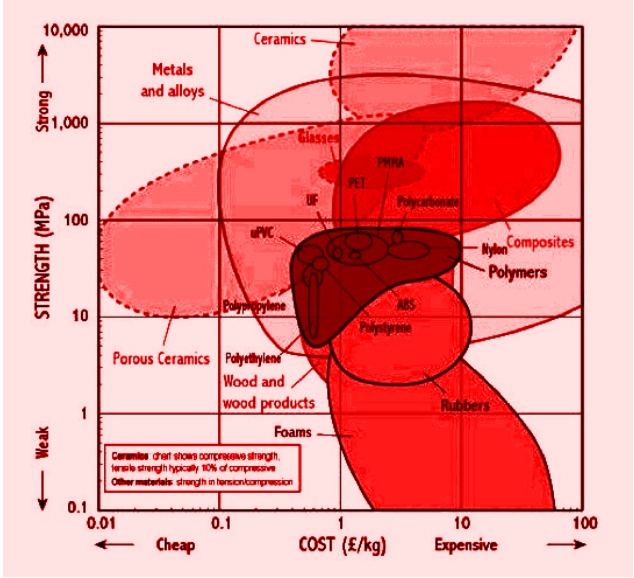



Fig. 4.07

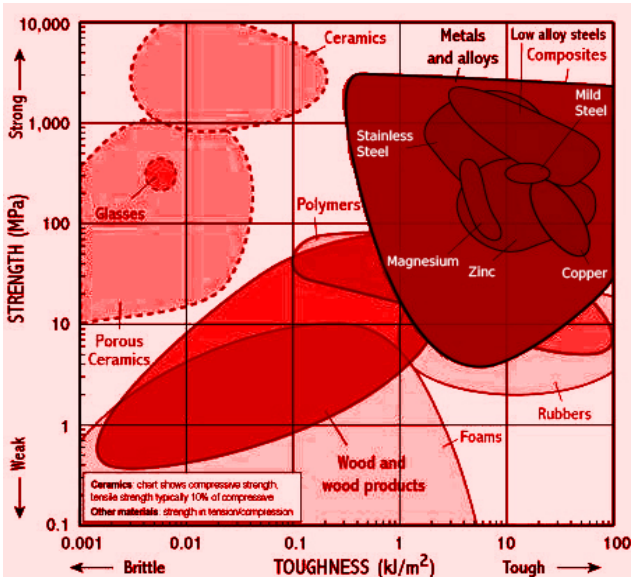



Fig. 4.08

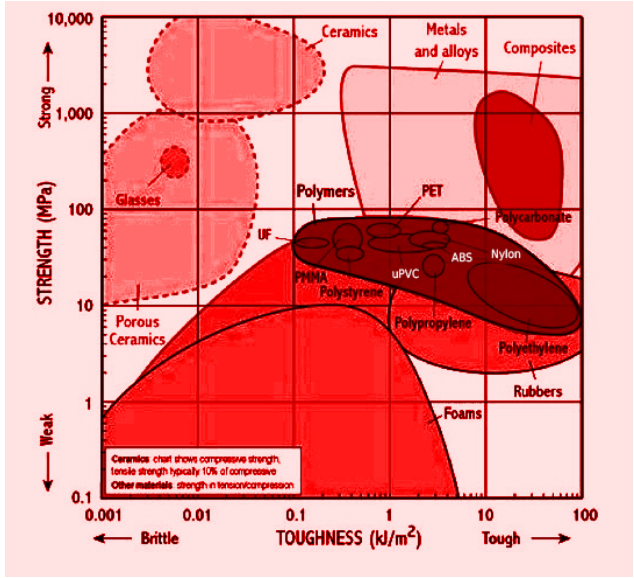



Fig. 4.09

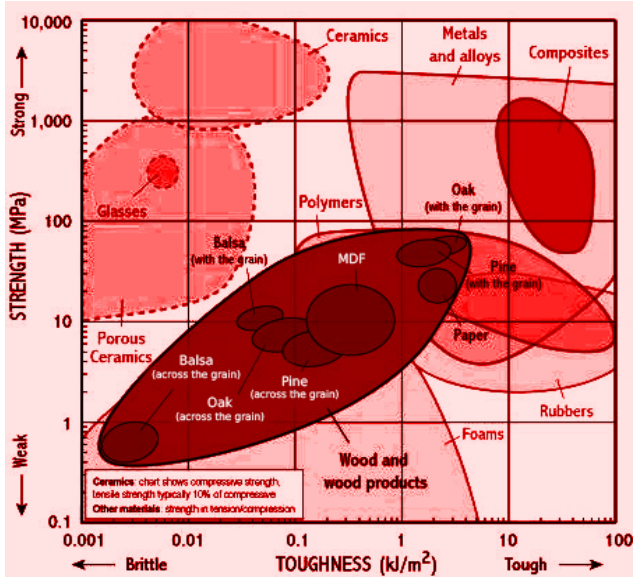



Fig. 4.10

Fig. 4.05 (opposite upper left)
Ceramic strength comparison.

Fig. 4.06 (opposite lower left)
Metal strength comparison 1.

Fig. 4.07 (opposite upper centre)
Cost comparison of polymers.

Fig. 4.08 (opposite lower centre)
Metal strength comparison 2.

Fig. 4.09 (opposite upper right)
Polymer strength comparison.

Fig. 4.10 (opposite lower right)
Wood and wood product
strength comparison.

Image D01 (top right)
adult termites

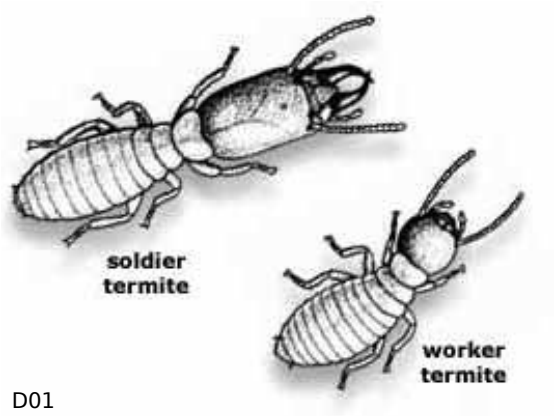
Image D02 (lower right)
Wood with termite damage.

such material.[3] Wood, bamboo, steel, and concrete/brick/stone materials are used for constructing semi-permanent/permanent structures. These materials require much more assembly time and shelter needs are immediate. Due to the high weight of these materials, this will increase freighting cost. Time constraints will not allow for the viable selection of these materials as emergency shelter.

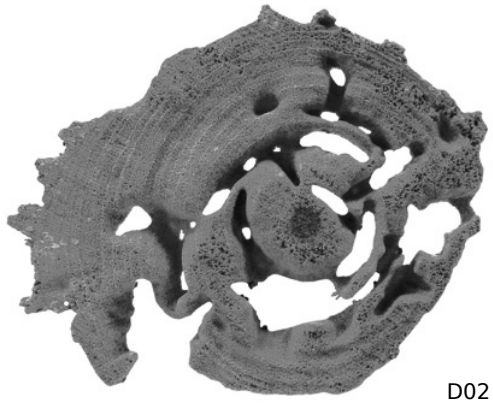
Synthetic and polymer materials in the market will perform more than adequately for emergency shelters. Current synthetic fabric materials viable for use with shelters weigh much less than 19mm plywood. Some fabrics weigh as little as 1% of 19mm plywood. These fabrics vary greatly in price though. A polyethylene tarp will cost 15% of 19mm plywood, while Tenara Architectural Fabric is 2000% more expensive.[4] [5] [6] Canvas materials or fabrics composed of organic fibres may be prone to damage from mold and mildew. Organic fabrics have a tendency to shrink if they are not properly treated and stored correctly, or are used in geographical locations with high amounts of precipitation.[7]

The structural components of emergency shelters must comply to weight limits as well. Suitable frame materials are: light gauge metals (galvanized steel and aluminium), bamboo, wood, and composite fibres such as carbon fibre or fibreglass.

Both wood and bamboo are susceptible to insect damage, and designer should exercise



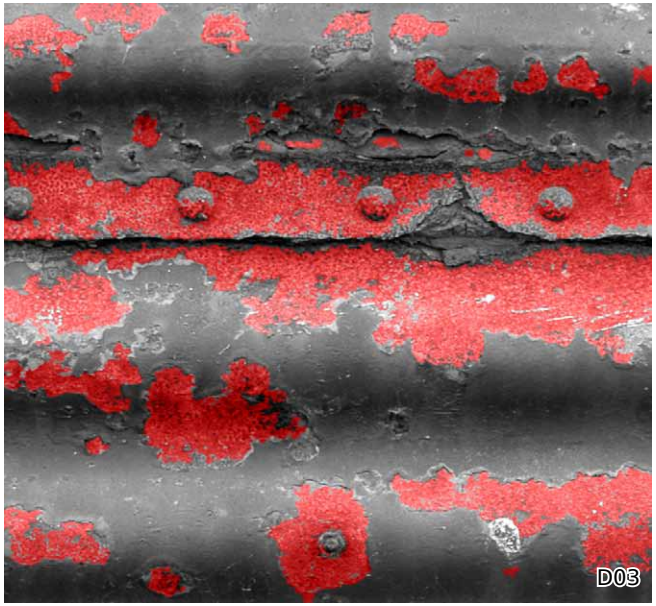

D01



D02

caution when specifying these materials in a termite infested areas.[8] [9] Termites will damage treated wood or bamboo if no other wood sources are available.[10] There can be adverse environmental effects from chemically treating wood or bamboo also.[11] Careful precautions must be taken to ensure there is minimal deforestation, and that timber is not logged illegally when sourcing it from the local market.

Metals are not prone to insects or mould, but they can oxidize (except for aluminum, which




oxidizes at an extremely slow rate). Accelerated oxidization of metal will be a concern for structures located in humid or rainy climates.[12] There also is the possibility that some beneficiaries who receive metal frame shelters will sell the metal as scrap for money and replace the metal framing with timber (which may or may not be from a sustainable source).[13] [14]

In hot climates, plastic framing materials may warp or deflect from the sun's heat and affect the shelter's ability to perform adequately. In such climates, shelters with plastic framing will cave inwards limiting the available headroom (Image B17).[15] [16] There are several engineered plastics that will not warp from intense heat that may be used as framing materials. These plastics are very costly in comparison to wood and light gauge galvanized steel.[17] The weight of engineered plastic varies between each type. Some are lighter than wood, while others are heavier.[18] Carbon fibre and fibreglass are both resistant to UV, mould/mildew, and insect damage. These will never oxidize and are lighter than wood.[19] Carbon fibre costs 100 times more than wood, and fibreglass is 10 times more expensive than wood.[20] [21]

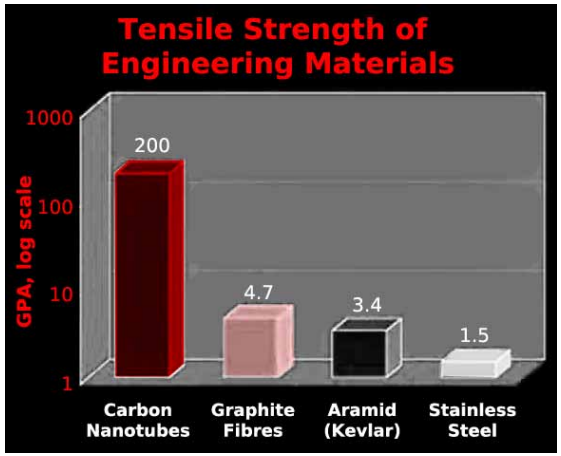




Fig. 4.11

## Connection Options

Due to the dimensional constraints imposed by shipping standards, long framing members must either be hinged, bolted together, screwed to each other end to end, friction fit, or roped with each other (Image D05). Decisions must be made on how


Image D03 (upper left) Rust damage on corrugated roof panel.

Image D04 (upper centre) Have these bamboo tent poles been harvested without damaging a region's ecological environment?

Fig. 4.11 (lower centre) Engineered polymers are 2 to 100 times stronger than steel.

the shelter skin material is fastened to the structure. Adhesion with glues/epoxies, screws, bolts, nails, nail plates, Velcro, rope, sewing, or rivets are among the ways one might fasten the skin to the frame. The weight of connection hardware must be taken into consideration, if these items are air freighted. Zips and Velcro should be avoided when fastening doors, windows, mosquito nets, and attaching skin to frame. Velcro often attracts and holds on to debris. This will make adhesion extremely difficult. Velcro is easily opened by intruders and offers zero sense of security. High quality zips are very costly and zips of poor quality fail (Image B27), leaving doorways flapping open.[1]

The shelter skin can be designed as one piece or can be constructed from several pieces of material. When a skin for a shelter is made from one piece, it eliminates extra hardware needed to attach the skin and the frame (Image D06).

D06

This will minimize the lapping required to seal the shelter from water penetration. If a single-piece skin needs repair from damage, the whole skin may need to be replaced. It is uncertain if areas on the shelter skin will wear at different rates and how this affects the longevity of the skin.

Since the shelter skin's depreciation will be disproportional, the optimum design may be to split the skin into several pieces (Image D07). If damage occurs to a shelter that is made from many skin pieces, it will be easier to replace the damaged skin piece instead of having to replace the whole skin. This system will require more hardware to attach the skin to the shelter frame and will increase the shelter construction time. Numerous seams in a multi-skin shelter would require design attention to ensure that the shelter is not penetrated by water.

Synthetic fabric shelters have a tendency to become quite uncomfortable in climates with extreme temperatures.[2] Ventilation will become a critical design factor to increase the shelter's satisfaction level within hot climates.

D07

A fly sheet (Image D08) is a secondary skin that may be integrated into the frame material of the shelter. Other types of fly sheets will have their own separate framework and there will be an airspace between itself and the emergency shelter. Some emergency shelters may require fly sheets due to the climate in which they are located. Fly sheets will add protection to organic fabrics by keeping the majority of water away from the shelter skin.[3] Most fly sheets will add extra material and weight when packaged with the emergency shelter during shipping. If emergency shelters were constructed with more robust skin materials and adequate ventilation was integrated within the design, the need for fly sheets would be eliminated.

D08

# Ground Cover

Some emergency shelters have a polyethylene sheet as a ground cover while others offer nothing. Shelters that do not have floor coverings will have water coming into the shelter after heavy rains. It is a common occurrence to have raw sewage flow throughout the camp during downpours.[1] [2]


Shelters without floor covering are more susceptible to harmful bacteria entering their shelter within rain water. People are concerned about contaminated water entering their living space.[3] Those that do provide ground covering come with either a separate ground covering, or an integrated ground covering that is attached to the shelter skin. The detached covering will not prevent water from entering the shelter. Many agencies have provided literature on how to prevent contaminated rain water from entering shelters.[4] What these agencies suggest (small drainage ditch around a shelter) will not help those dealing with heavy rain falls and short term rising water tables. This will not prevent water penetration from flash flooding.


There are several options to prevent water from entering the living area. Elevating the shelter is the most direct solution for the problem.[5] Building a platform raised on stilts is one way to accomplish this while mounding earth is another way. The height of these platforms can be determined from recorded rainfall data during previous heavy rainfalls. If this information is not available, a range of 150 mm and upwards of 600 mm should be sufficient. Stairs will need to be incorporated within the platform design if the A wood plank floor built from gathered debris on top of a polyethylene ground sheet would work to prevent punctures from furniture. A wood plank floor would also work well on top of the mounded earth platform. In regions with no rainfall, floors may be dug into the earth.[6] Digging floors into the earth will increase headroom and will help to keep the shelter cooler.


Image D09 (centre left)
Child walks through a flooded camp in Port-au-Prince, Haiti.

Image D10 (centre)
Open sewer running around a home in Mathare, Nairobi, Kenya

Image D11 (centre right)
Shack on stilts in Vietnam.

# Aid Logistics

There are many ways to transport materials throughout our world. Airfreight is currently the most expensive way to transport goods (space travel is not included in this list, nor underwater transportation), followed by road transportation. Rail transportation is the least flexible transportation option, but it is still a very affordable option. Containers loaded onto sea freighters is the least-expensive mode, this transportation requires a lengthy time duration to reach its destination.[1]

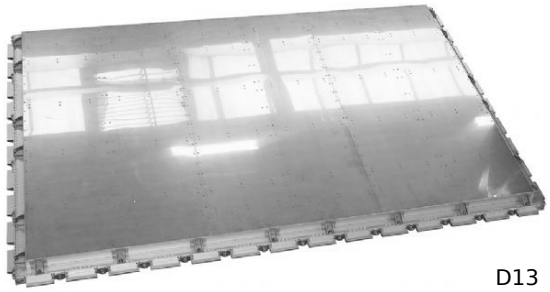
The transportation industry has developed loading and shipping tools that are interchangeable between each mode of transportation. The common pallet is an example of these tools, typically measuring 1m x 1.2m (Image D12), it can be made of wood, metal, plastic, or cardboard and is capable of supporting 900 kgs or more, depending on pallet material type.[2] It is one of the smallest loading tools used in the shipping industry and is commonly loaded by forklifts into tractor trailers or ISO shipment containers.

The military uses another type of pallet that is much larger and is generally used for airfreight purposes. This pallet is called the 463L cargo pallet (Image D13) it has a dimension of 2.7m x 2.2m and a weight carrying capacity of 4,500 kgs. This pallet is compatible with international military cargo handling equipment and some commercial wide-bodied air freighters. The 463L pallet is typically used with C17 and C130 cargo planes. This pallet is also used within the humanitarian industry when goods are being shipped from donor nations via military aircraft.

The commercial air transportation industry uses another type of container called a unit load device (ULD), which is loaded into wide-bodied airliners. There are several different shapes and sizes for these containers (Image D14). They range in size from 4.25 $m^3$ with 1,600 kg capacity to 12.7 $m^3$ with 5,000 kg capacity. The height of ULD containers will never exceed 1.57 m, which will allow it to fit in cargo doors. Widths will vary from 1.37 to 2.33 m, and length varies from 1.47 to 3.04 m.[4]

A major part of all freighting is done with ISO shipment containers and there are several standard sizes. The two most common sizes worldwide are the 6m (Image D15) and 12m container. They are also manufactured in 3m, 9m, 14m, 15m, and 16m sizes.[5] Over 90% of the world's non-bulk goods are transported in ISO freight containers.[6] The typical 6 m ISO container has an exterior dimension of 6 m length, 2.4 m width, and 2.4 m height and the

D12



D13

D14

interior dimensions measure 5.7 m length, 2.34 m width, and 2.38 m height. The volume for this container is 33.1 $m^3$. It has a weight of 2,300 kgs, and can load (net) 21,700 kgs. The typical 12 m ISO container has an exterior dimension of 12.2 m length, 2.43 m width, and 2.43 m height and the interior dimension's measure 12 m length, 2.34 m width, and 2.38 m height. The volume for this

D15

container is 67.5 $m^3$, and it has a weight of 3,600 kgs, can load (net) 26,700 kgs.[7] [8] Although ISO containers can carry substantial weights, the loading maxim is dependent on the type of transportation in use and the capacity of the handling equipment (Image D16) at loading facilities.

Transporting materials after a natural disaster is one of the most difficult obstacles to overcome. Conditions at sea ports may make shipments impossible. The airport may be destroyed along with roadways and railways (Image D17). Regrettably, these conditions will dictate how material is transported to the affected area and within it. Logistics costs will vary between each disaster. To overcome delivery delays for all port conditions, it will be necessary to work within the boundary limits of each port.

For instance, if heavy equipment is available at airports 6 m ISO containers can be loaded on 463L pallets for equipment is available at airports

D16

6 m ISO containers can be loaded on 463L pallets for air freight. 6 m ISO containers are more interchangeable between transportation modes in comparison to the 12 m ISO container. The 12 m ISO container may have weight restrictions in place while being transported by road within certain countries, this may make it a less economical option.[9] It will cost somewhere between $3,000 - $5,000 USD to ship 6 & 12 m ISO containers via sea.[10]

After a disaster initial goods to be shipped in

D17

will be through air freight. The most common articles that will be shipped are: food and water, medical supplies, search and rescue teams, aid personnel, military/construction handling equipment, some clothing articles (blankets), field hospitals, water purification equipment and generators, and emergency shelter.[11]

Within the first 72 hours following a disaster, agencies must expect the tarmac at the airport to be extremely congested (Image D18). This congestion may delay emergency supplies due to little coordination between agencies and inaccurate

decisions made from a lack of information.[12]

All major reconstruction equipment and materials typically will not arrive until a few months following the disaster.[13] This material will generally arrive by sea freight in 6 m & 12 m ISO containers and will prevent further costs from air freighting in material.

Other delays may be incurred from damaged interior roadways and railways.[14] In some cases emergency relief and reconstruction material will have to be air lifted via helicopters to remote rural areas inaccessible by road passage.[15]

Section Summary:
Triangles are strong with loading, domes are best in wind loads, and squares/rectangles divide space well in plan. Wood/bamboo can rot and be damaged by insects, steel is heavy and will rust, engineered plastics/polymers are strong and expensive. Shipping by sea is the least expensive, while air freighting is the most expensive. Shelters in areas prone to precipitation should be elevated. Use of quality connectors is recommended in shelter design, they are prone to failure.

In next section:
The design section (Development) will immediately follow this one. The design of a new disaster relief tent is the purpose of this section. It shall take into consideration all of the important points made from the previous sections.

Design considerations:
- a choice will be made to either focus on shape or efficiency
- materials must be light-weight to reduce shipping cost
- shelter location will affect how it attaches to the ground and whether or not it must be raised
- select light-weight robust connectors that minimize the

Image D18 (right)
Aérodrome de Jacmel, Jacmel, Haiti.
Just hours after the 2010 earthquake, planes began arriving with relief goods.

D18

## Strength or Efficiency?

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#3
Nut
slot
area
connection loop
addition of vertical sides
strength?
slotted
brace
location
by adding
a second ring
connector
(without second loop)
similar to
or
standard
is there a way to connect
another brace to the center?
It would essentially work like a


DEVELOPMENT


E01

# Proposing an Alternative: Design Brief

"The best security for civilization is the dwelling, and upon properly appointed and becoming dwellings depends, more than anything else, the improvement of mankind." - Benjamin Disraeli[1]

Image E01 (opposite)
A Haitian women sits next to her tent that has been destroyed from Tropical Storm Isaac. Isaac struck Haiti in August of 2012. This tent was supplied to her after the Earthquake of 2010, and most likely was in need of repair a year prior to Tropical Storm Isaac. Unfortunately, this is yet another example of why emergency shelters should be a more robust shelter solution.

It is the intention of this thesis to design a plausible unique shelter solution for regions affected immediately following a disaster. This new shelter solution may fall under the classification of a tent. The tent will be designed to operate comfortably within locations around the world above the Tropic of Cancer at latitude 40°N and below the Tropic of Capricorn at latitude 40°S. This shelter will not operate as a four-season tent. Winterizing this design may be pursued in the future, however, using this shelter in cold climates will not be considered an option within this thesis.

The shelter to be designed will offer a selection of different materials that humanitarian agencies can choose. The shelter may be tailored to suit each specific sub-region inside 40N to 40S of the globe. Some options of this shelter design will target specific demographics of the population in distress. An optimum design will be presented as a solution for the elderly, disabled, and other vulnerable persons. It should resist wear and damage for a minimum of two years.

This new shelter option will explore cutting-edge polymer fabric material possibilities that have the increased security resistance. Non-ferrous and non-wood framing options will be explored due to their ability to resist mold/mildew, corrosion, and insect damage. Ground cover should be supplied with the shelter. This will come in the form of a polyethylene sheet. More robust materials

(see page 134 for end notes)

must come from the location of the disaster area, because stronger floor materials will increase shipment weight. Stilts will also have to be built with materials from the location of the disaster region. They will be required if land selected for camp location is in an area that may be prone to flooding, or to mitigate against unknown flood dangers.

Ventilation and the promotion of airflow throughout the shelter will be very important to the design of this shelter. Outdoor living space is another needed option for hot climates. This will be another important design element that needs to be added into the final solution. This design must also have strong fasteners that prevent windows/doors/vent openings from ripping off or damaging the tent in high wind scenarios. Neither Velcro nor zippers will be used as clasping/fastening devices on this shelter. Both have a tendency to fail when used in field operations.

The shelter must be designed so that it can transport easily within standard 6 m & 12 m ISO containers. A reusable container to hold the skin and other parts of the shelter may be incorporated into the design. This container must stack well for shipping purposes.

The Sphere Standard suggestion of 18m² for a shelter area will be used as the total living space within this design. By using the Sphere Standard 18m² floor area suggestion as a guide, this shelter will be able to accommodate five people.

# Method of Design

Wind simulations and materials comparisons were utilized in this thesis to determine which materials and shapes should be explored further. During this process almost one hundred different sketches were made and narrowed down into three distinct frame typologies.

Frame type 1 used a fabric panel system to construct the shelter. This system was too heavy and required many individual parts for its assembly. Frame type 2 was an improvement upon type 1, initially using a space frame hub. Next, a new connector piece was developed to improve the design and eliminate unnecessary connections. However, the type 2 system was still too heavy and had an excessive amount of individual pieces. If one piece were to go missing, the shelter could not be completed. Frame type 3 was a drastic change from the two previous frame designs. The strategy behind the design was to bend two upright walls on top of one another. The resulting shape is similar to a barrel or half cylinder. Frame type 3 was not connected together through the frame, but rather the skin.

Frame type 3 is shown as design 4 (bowstring 1) and design 5 (bowstring 1) in Image E01. These shapes were chosen for further study due to their rounded shape and less complicated connecting hardware. The rounded shape allows wind to pass over the structure easier than the flat roofs of designs 1, 2, and 3 (panel, grid 1, grid 2). The round shape of design 4 & 5 performs well at shedding water of the roof. Water pooling on the roof may have been a problem with designs 1, 2, and 3. Design 4 & 5 do not have overly complicated hardware compared to designs 1, 2, and 3. Design 4 & 5 can be assembled with standard nuts and bolts that are accessible worldwide. In contrast, designs 2 & 3 have complex connectors that are not readily available in times of need. For these reasons, design 4 & 5 were selected for future exploration.

Design 4 is the shape of a Roman arch and design 5 is the shape of a Gothic arch. Both shapes will be compared against one another in the wind simulation analysis. For the remainder of this thesis, the shelters that come from the bowstring design will be called: BWSTR, an abbreviation of the word bowstring.

The rose diagrams in Fig. 5.01 contrast the strengths and weaknesses of each shelter design. Points located towards the outer edge of the radar circle indicate shelter design strengths.

Fig. 5.01 (opposite)
Comparison of shelter designs in sequence.

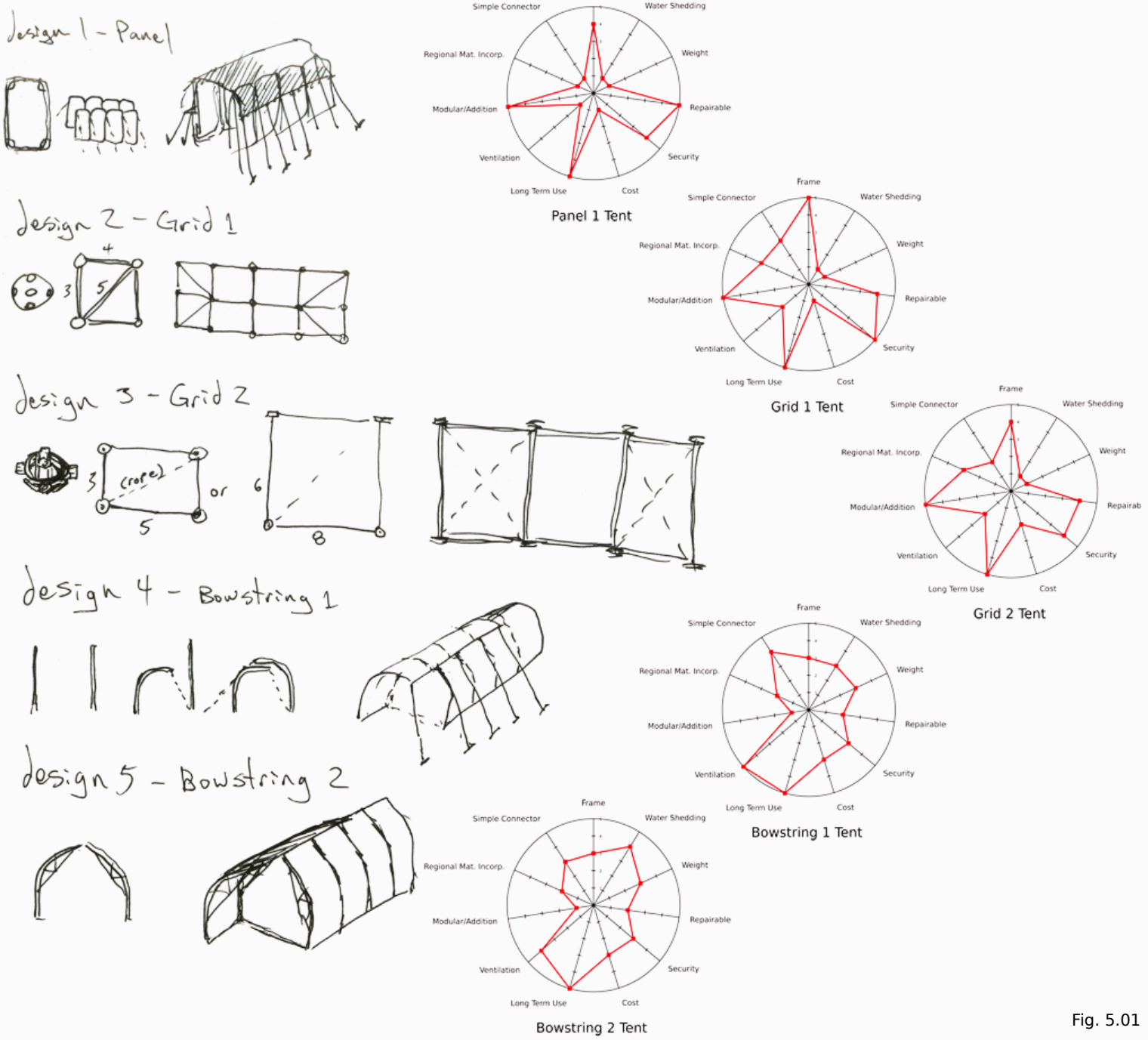

Design 1 - Panel
Design 2 - Grid 1
Design 3 - Grid 2
(rope)
or
Design 4 - Bowstring 1
Design 5 - Bowstring 2
Frame
Water Shedding
Weight
Repairable
Security
Cost
Long Term Use
Ventilation
Modular/Addition
Regional Mat. Incorp.
Simple Connector
Panel 1 Tent
Grid 1 Tent
Grid 2 Tent
Bowstring 1 Tent
Bowstring 2 Tent

Fig. 5.01

## Analytical Design Process

The following pages highlight the various tests, calculations, and experiments used to determine the final shelter design shape.

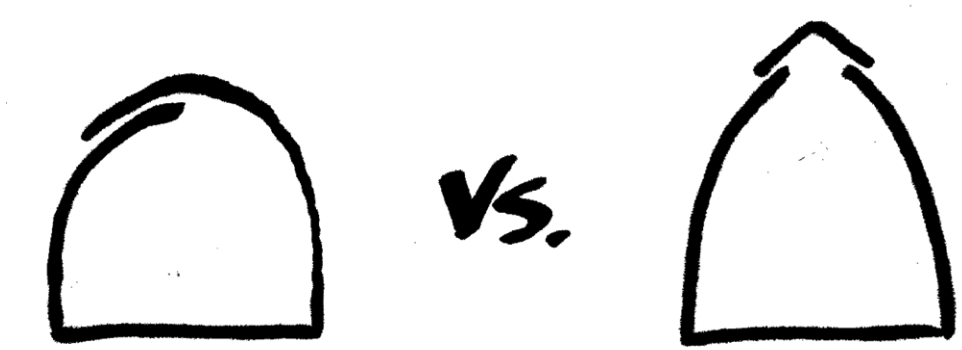
## Wind Simulation Test

Two design shapes were presented (Image E02) as viable options for the development of the shelter using the frame type 3 design. The two options included the standard arch/barrel shape and the Gothic arch shape. The significance of the Gothic arch shape is the integrated ridge vent that extends down the entire length of the shelter.

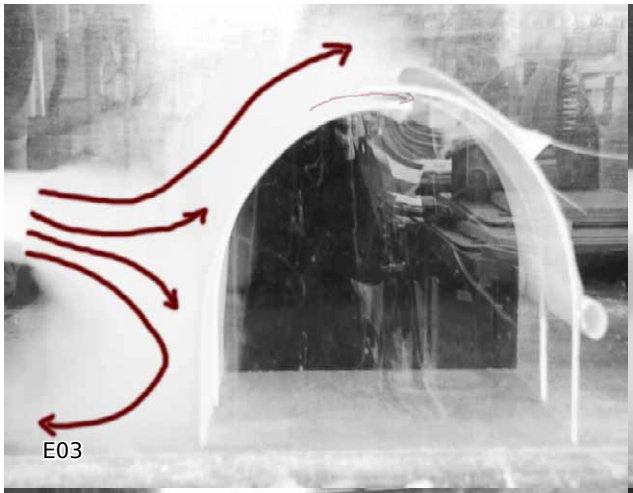
A one-tenth scale model was created for each design shape. Openings were added along both sides of each shelter to replicate windows for the experiment. The models were then placed inside a clear Plexiglas chamber. A smoke machine was placed at one end of the chamber and a fan at the opposite end. The smoke machine and fan were turned on. Smoke passed over the shape of the model and the path of wind was made visible.

It was hypothesized that the Gothic arch shape would be the superior design for flow and ventilation through the shelter. This hypothesis was supported by the belief that the continuous ridge vent across the top would aid in ventilation.

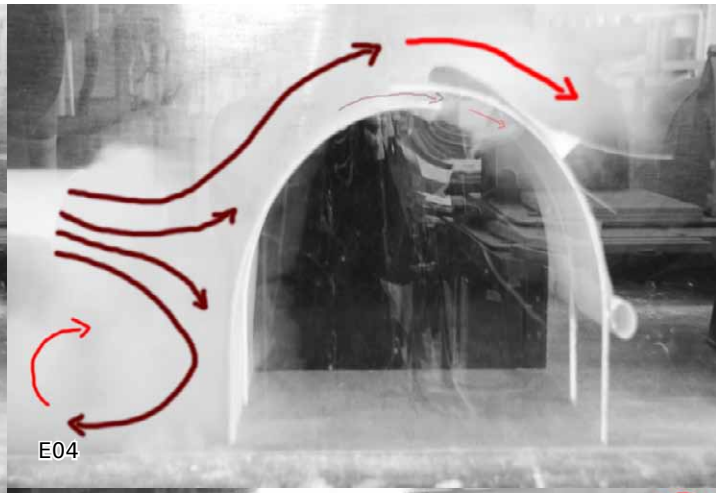
However, when tested, the Gothic-shaped structure performed poorly compared to the barrel-shaped structure. The barrel shape model showed



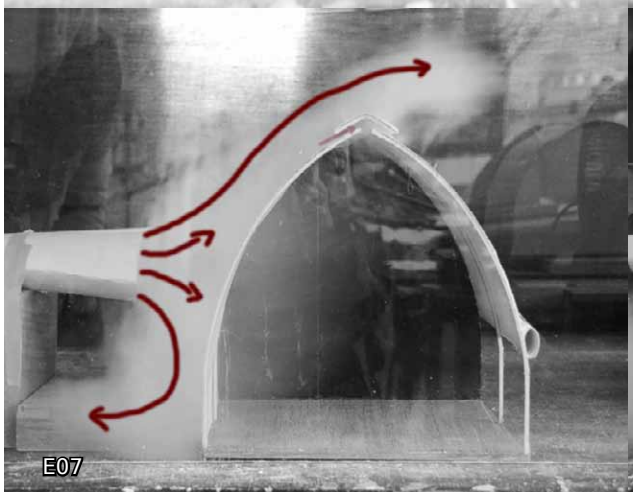

E02



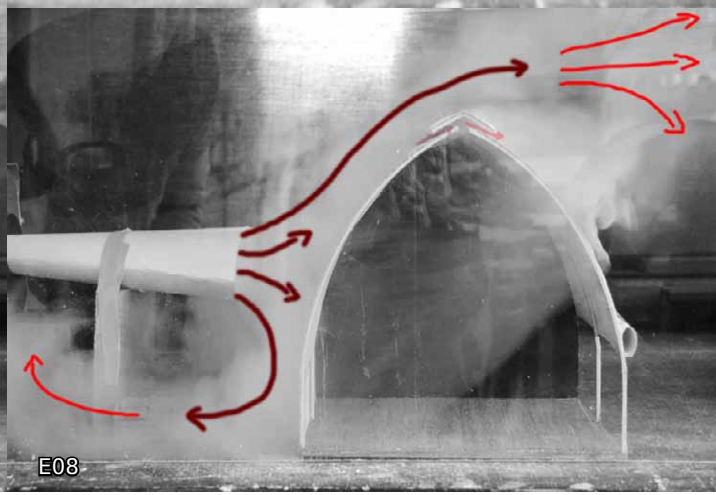
E03



E04



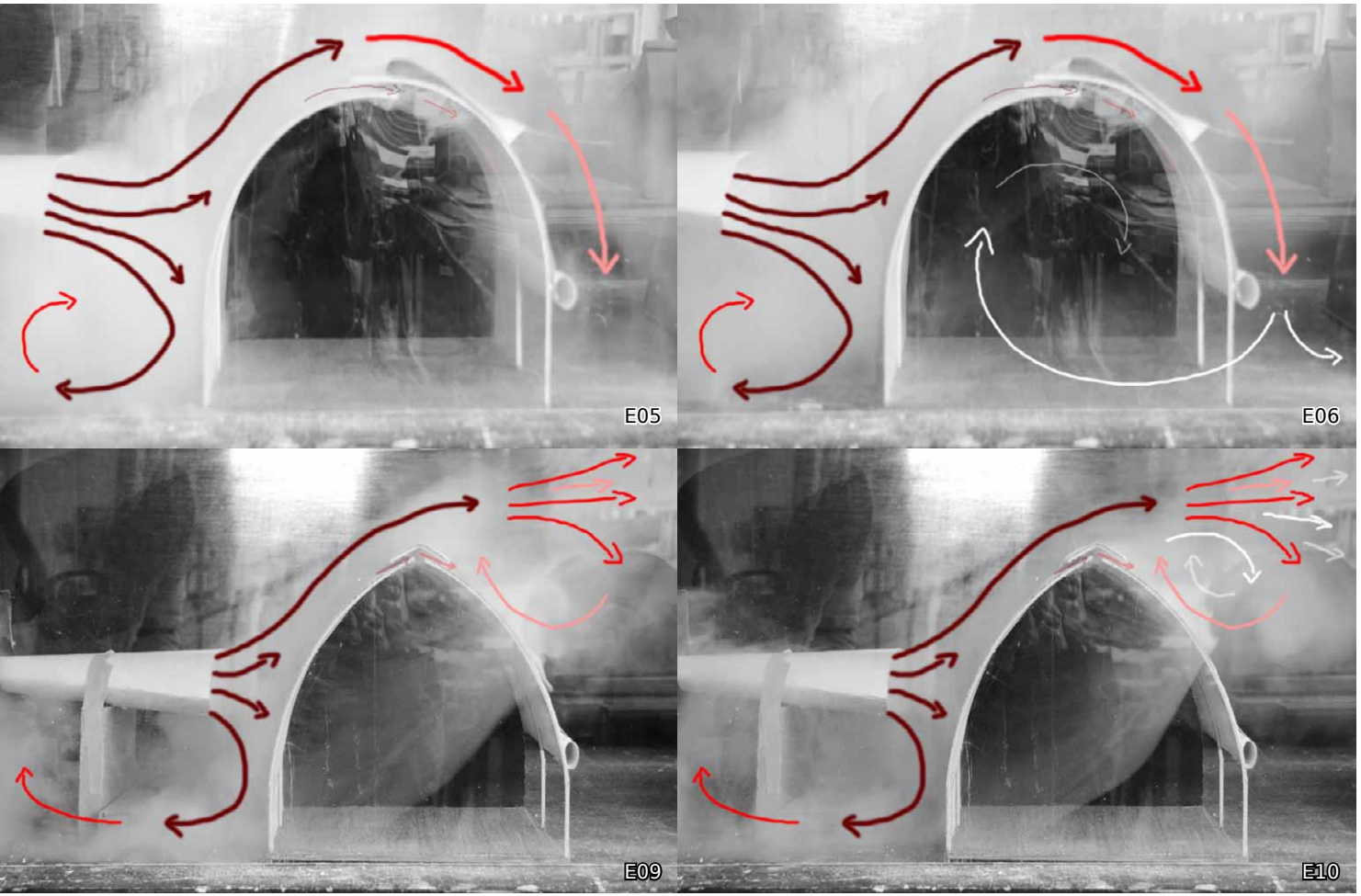
E07



E08

that indirect wind passed into the shelter on the leeward side forming a small eddy (an eddy is a swirling reverse current created when a fluid or air flows past an obstacle). Wind within this eddy was able to travel inside the shelter. In the Gothic shaped model, the wind eddy formed further away from the shape which did not allow for indirect wind to enter the shelter on the leeward side.

After the wind simulation test, it was determined that the Roman arch shape should be pursued as the selection for warm climates. Air flows inside this shelter, even from the leeward side. This may be beneficial if the wind force is too strong on the windward face of the shelter. The Roman arch shape was chosen because of its superior ventilation and wind flow properties.




Images E03 - E10 (both pages)
Screenshots taken from the smoke simulation test. Arrows are drawn on the image to show wind patterns.

# Extended Deformation Test

A piece of fibreglass rod was bent in an arch by a steel cable and held there for approximately 60 days. The results of this test will determine if fibreglass will have a permanent deformation after being held in an arch position for this period of time.

Depending on resin type used to create the fibreglass rod, this rod should have little to no permanent deformation after being held to a shape for an extended period of time.

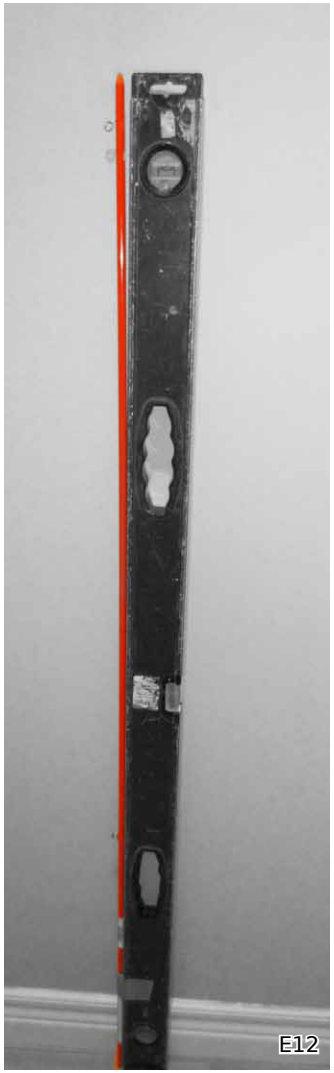
Observation: After 60 days the cable that was used to keep the rod in tension was cut. The rod was then placed beside a level. There was a minuscule bend in the rod, perhaps 1-2°, but less than 5°.

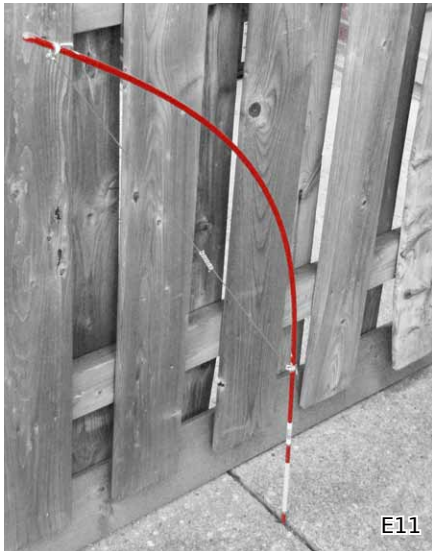
Conclusion: It is uncertain how far the life scale frame will deform after being held bent for long durations. Further testing is required to determine how much and how long the frame deformations will last.

Suggestions: Pipes should be strapped together during transport. This will aid in the stacking of strapped together shelter frames and help keep the frames straight.

Images E11 (top right)
Photograph of rod in testing environment.

Images E12 & E13 (bottom)
The result after 60 days of being bent.
A very miniscule bend present in rod.


E12


E11


E13

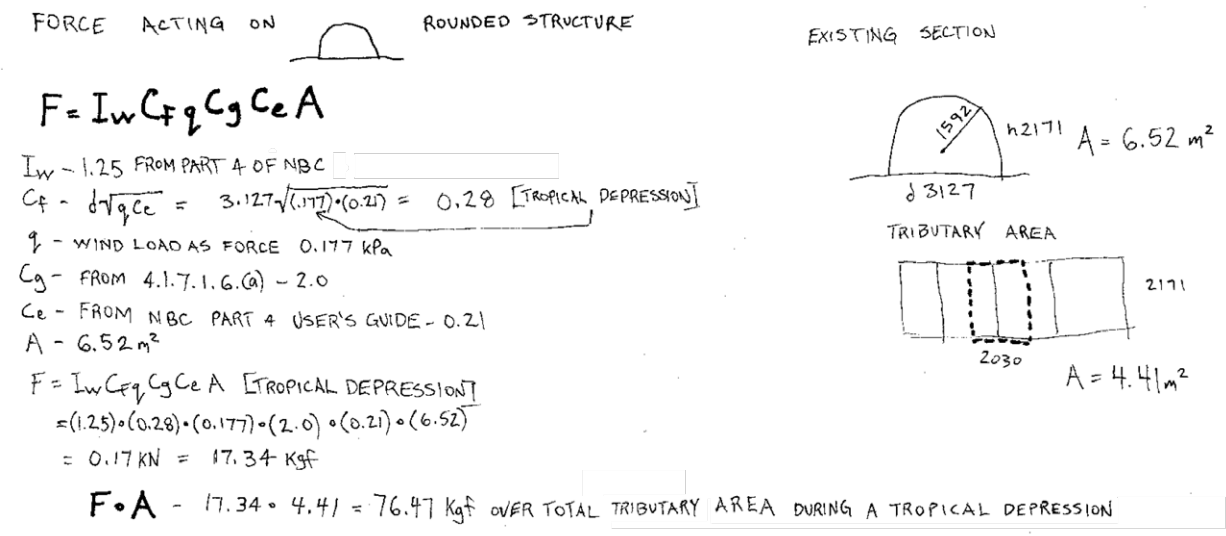
# Wind Load Calculations and Material Strength Comparison

The wind loads were calculated from a tropical depression to a category 5 hurricane load force acting on the shelter. After the force is calculated for each wind load on the structure, failure rates are listed for each material.

Wind Load factors:
Tropical depression - 17 m/s – 0.18 kPa – 18.05 kgf/m²
Tropical Storm – 18-32 m/s – 0.38 kPa – 39.15 kgf/m²
Category 1 – 33-42 m/s – 0.86 kPa – 89.23 kgf/m²
Category 2 – 43-49 m/s – 1.3 kPa – 132.56 kgf/m²
Category 3 – 50-58 m/s – 1.77 kPa – 179.98 kgf/m²
Category 4 – 58–70 m/s – 2.51 kPa – 255.95 kgf/m²
Category 5 - >70 ms – 3.02 kPa – 308.06 kgf/m²

See Image E14 for the example calculations. The rest of the totals are as followed:

Tropical depression – 0.17 kN – 17.34 kgf – 17.34 kgf on tributary area
Tropical Storm – 0.5 kN – 50.99 kgf – 224.87 kgf on tributary area
Category 1 hurricane – 1.8 kN – 183.55 kgf – 809.46 kgf on tributary area
Category 2 hurricane – 3.34 kN – 340.59 – 1,502 kgf on tributary area
Category 3 hurricane – 5.26 kN – 536.37 kgf – 2,365.4 kgf on tributary area
Category 4 hurricane – 8.92 kN – 909.57 kgf – 4,011.2 kgf on tributary area
Category 5 hurricane – 11.79 kN – 1202.24 kgf – 5,301.9 kgf on tributary area




E14

Material force resistance capabilities
Tongue tear test failures for fabrics:
Polyethylene Tarp – 0.52 kPa – 53.03 kgf/m² (* 4.41 = 233.86 kgf in 4.41m²) – almost failure at Tropical Storm
100 gsm Ripstop Nylon – 0.67 kPa – 68.32 kgf/m² (* 4.41 = 301.29 kgf in 4.41m²) – Category 1 failure
560 gsm Canvas – 1.67 kPa – 170.29 kgf/m² (* 4.41 = 750.98 kgf in 4.41m²) – Category 1 failure
PVC-Coated Polyester – 2.52 kPa – 256.97 kgf/m² (* 4.41 = 1,133.24 kgf in 4.41m²) – Category 2 failure
1100 Dtex Polyester – 4.79 kPa – 488.44 kgf/m² (* 4.41 = 2,154.02 kgf in 4.41m²) – Category 2 failure (almost Category 3 failure)

Break strength of solid braid nylon rope:
6mm – 850 kgf – almost failure at Category 1

Fibreglass pipe tensile strength – 110.32 Mpa

Holding power of earth spiral anchor – 227 kgf – Tropical storm failure

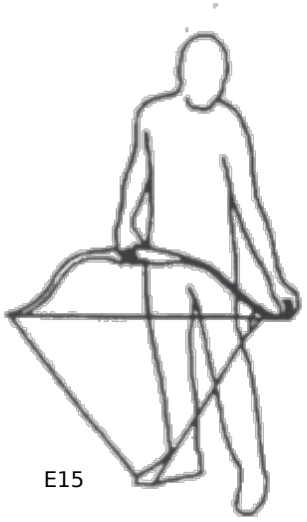
Holding power of ground screw – 2000 kgf – Category 2 failure (almost Category 3 failure)

Conclusion: In theory, the use of robust fabrics such as heavy canvas and PVC-coated polyester should ensure the survival of the shelter during tropical depressions and hurricanes up to category 2 in strength (this does not include projectiles within those winds, and it is recommended to proceed to communal storm shelters in the event of an actual typhoon or hurricane).

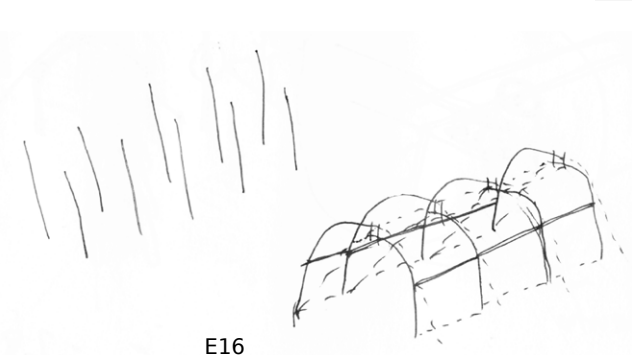
# Design Inspiration

The inspiration for the BWSTR Series shelters came from the process of stringing a bow. A bow takes its shape when a string shorter than the length of the bow is attached to both ends. Since this string is shorter than the length of the bow it causes the ends of the bow to bend towards one another. Similarly, the thesis design has a frame that is bent from the tension of a rope.

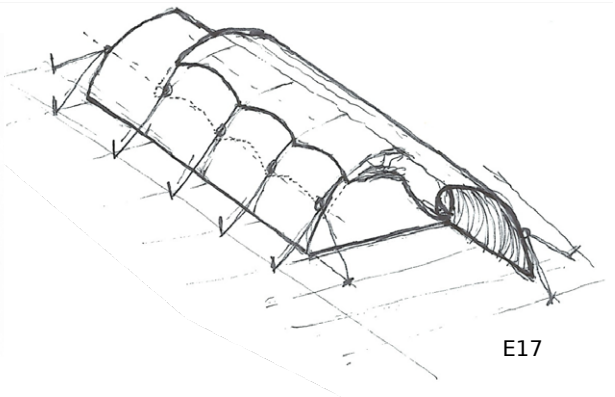
As the walls become the roof, this technique eliminates the extra connections and materials otherwise associated with a roof assembly. The upper skin has a flap that attaches to the lower skin. This flap may fold over itself, which allows for greater ventilation in hot climates.



E15



E16



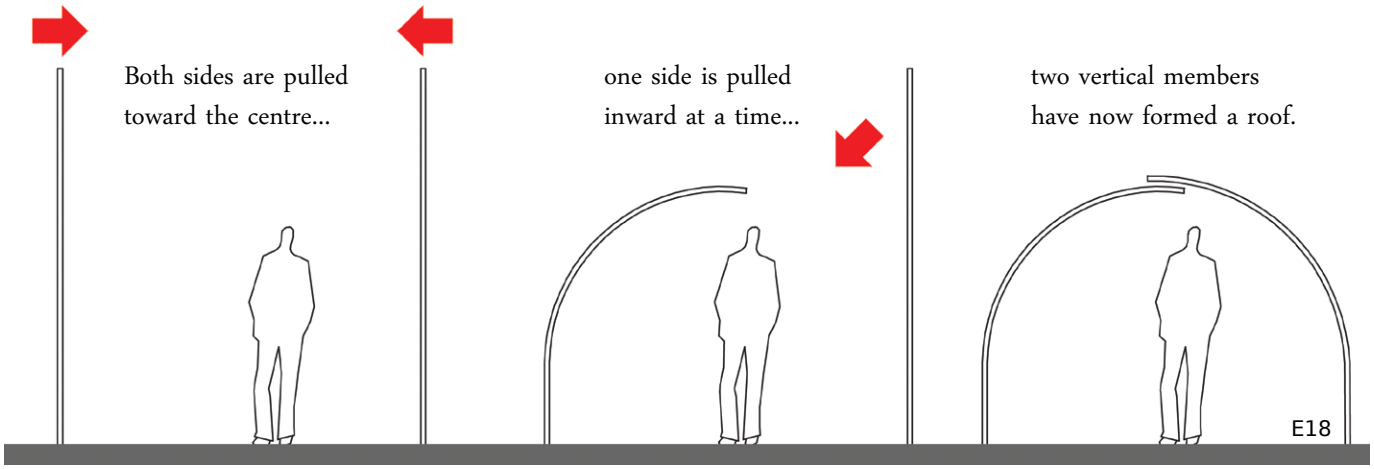
E17

Image E15 (top right)
Illustration of how to string a bow.

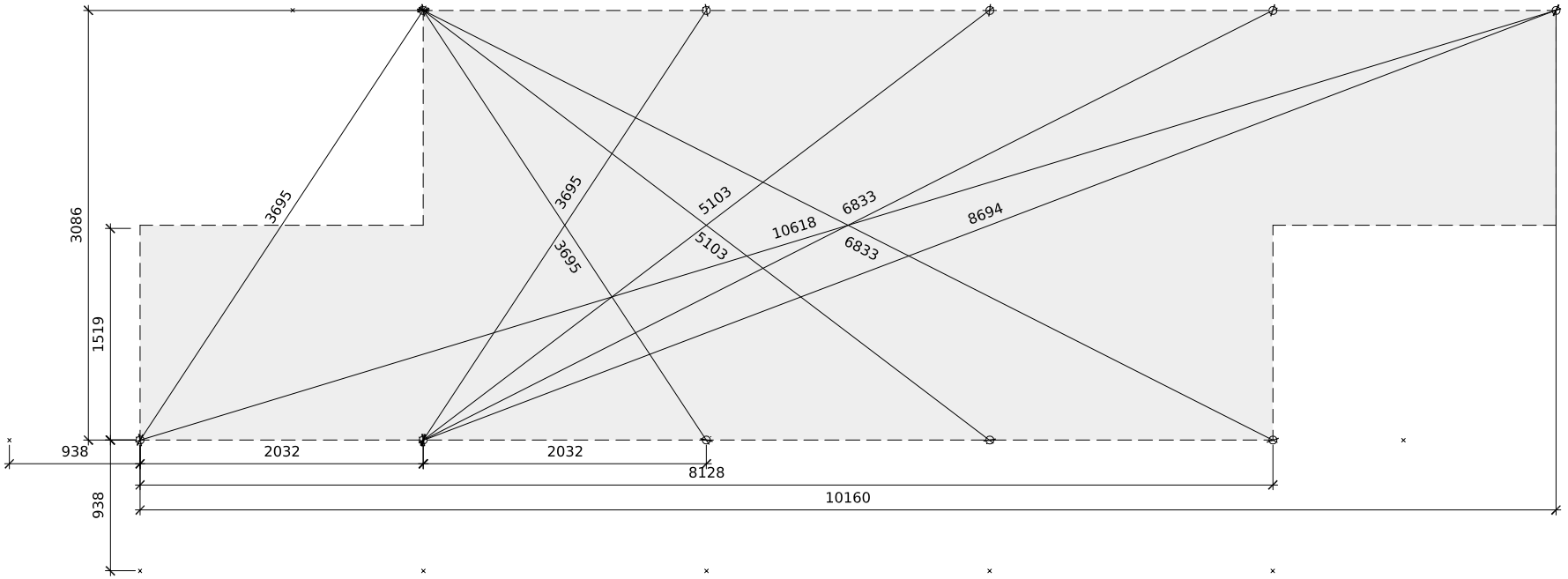
Image E16 (centre)
The initial sketch that lead toward the final design.

Image E17 (centre right)
A sketch several iterations after the initial sketch.

Images E15 - E18 (this page)
The design concept explained diagrammatically.



# BWSTR Series Technical Drawings
(All measurements presented in mm)

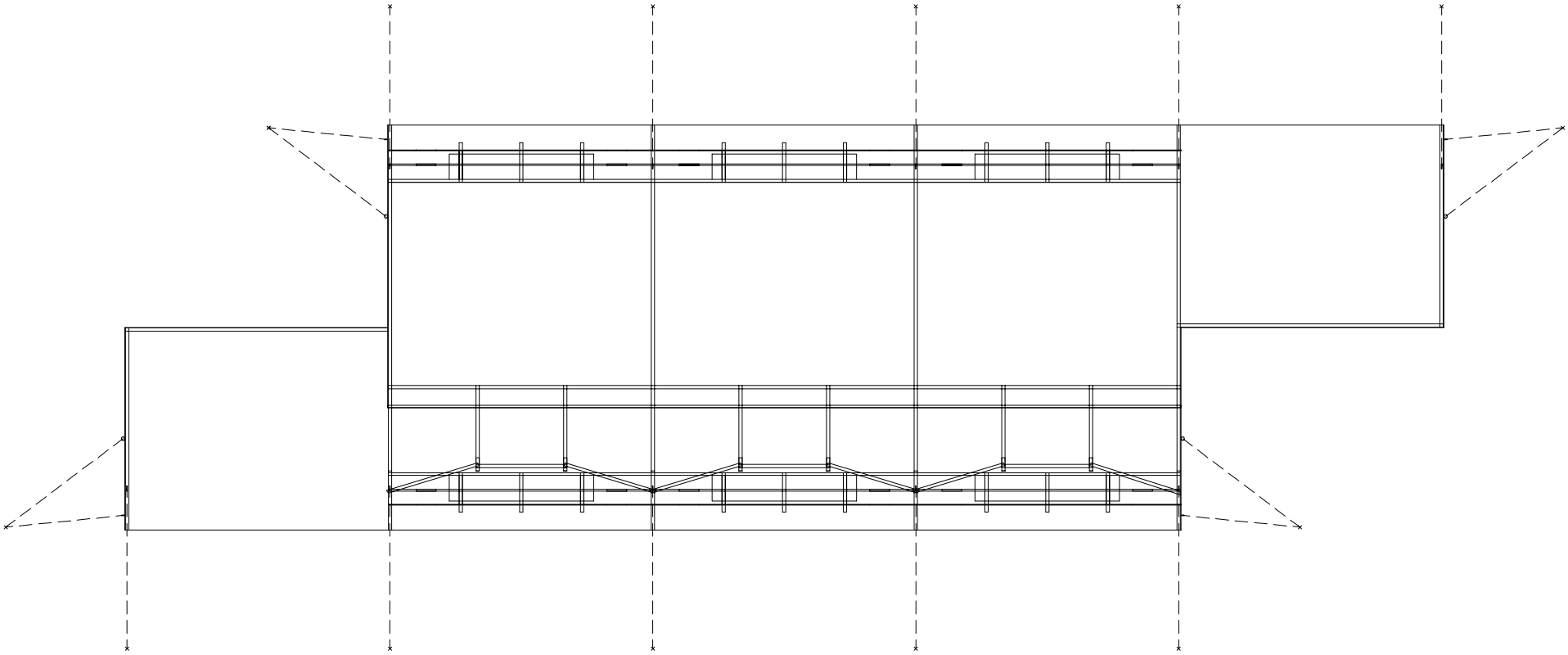




## Site Layout Plan (NTS)

E19

Images E19 - E30 (following pages)
These images are the drawings required to erect and assemble the BWSTR Series emergency shelter system.




Roof Plan (NTS)

E20

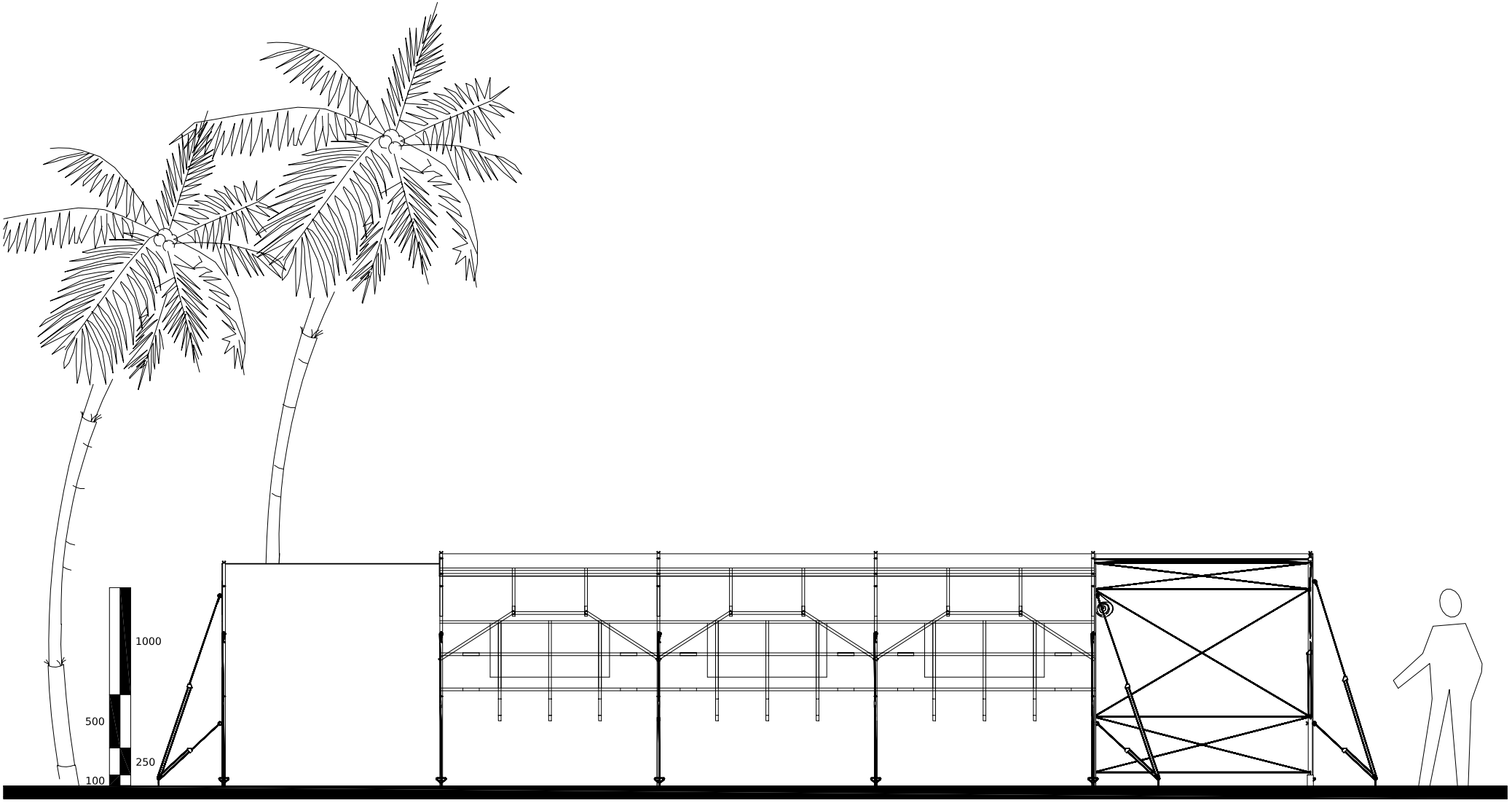



Diagram Elevation 1 (NTS)

E21

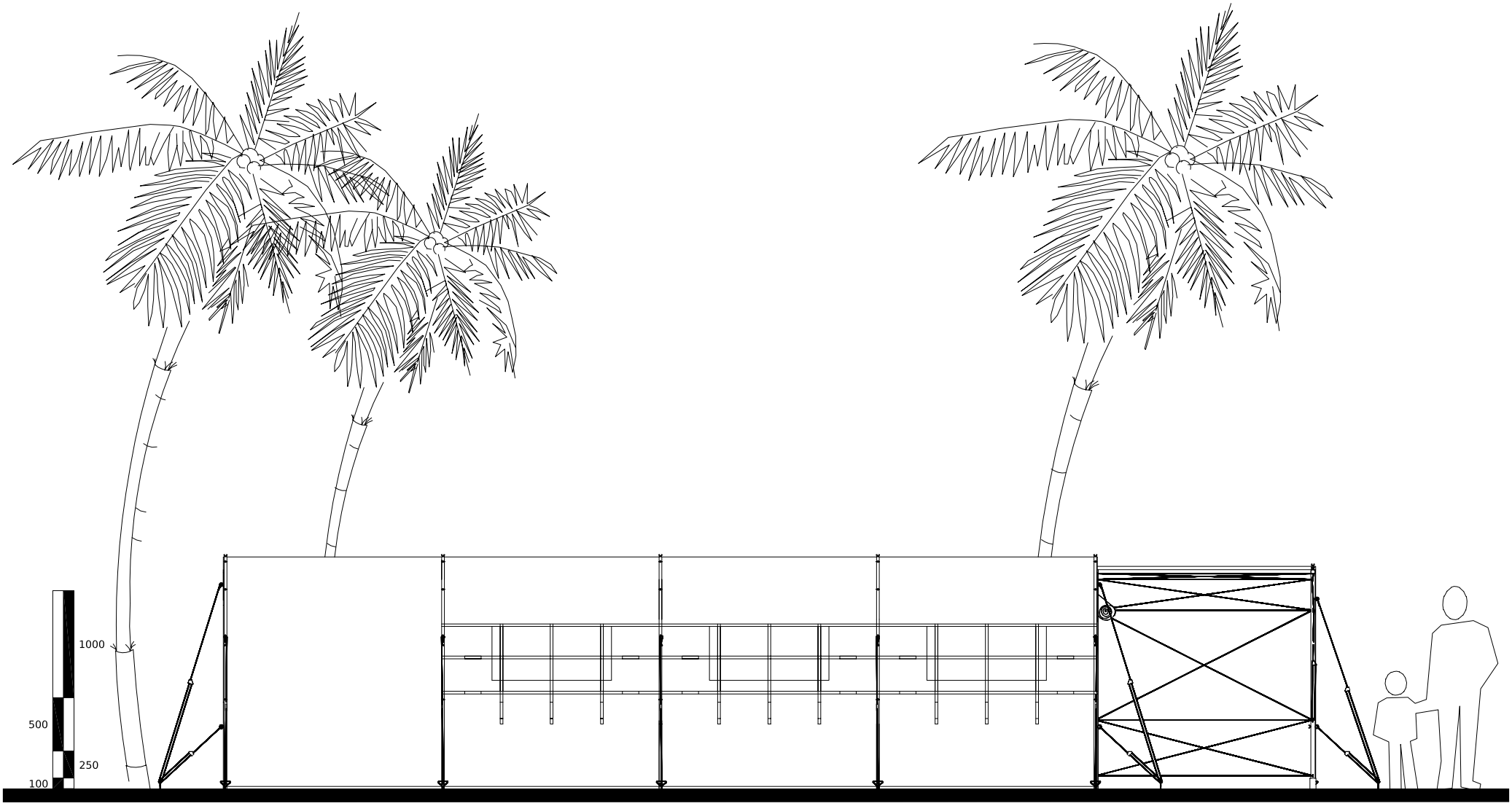



Diagram Elevation 2 (NTS)

E22

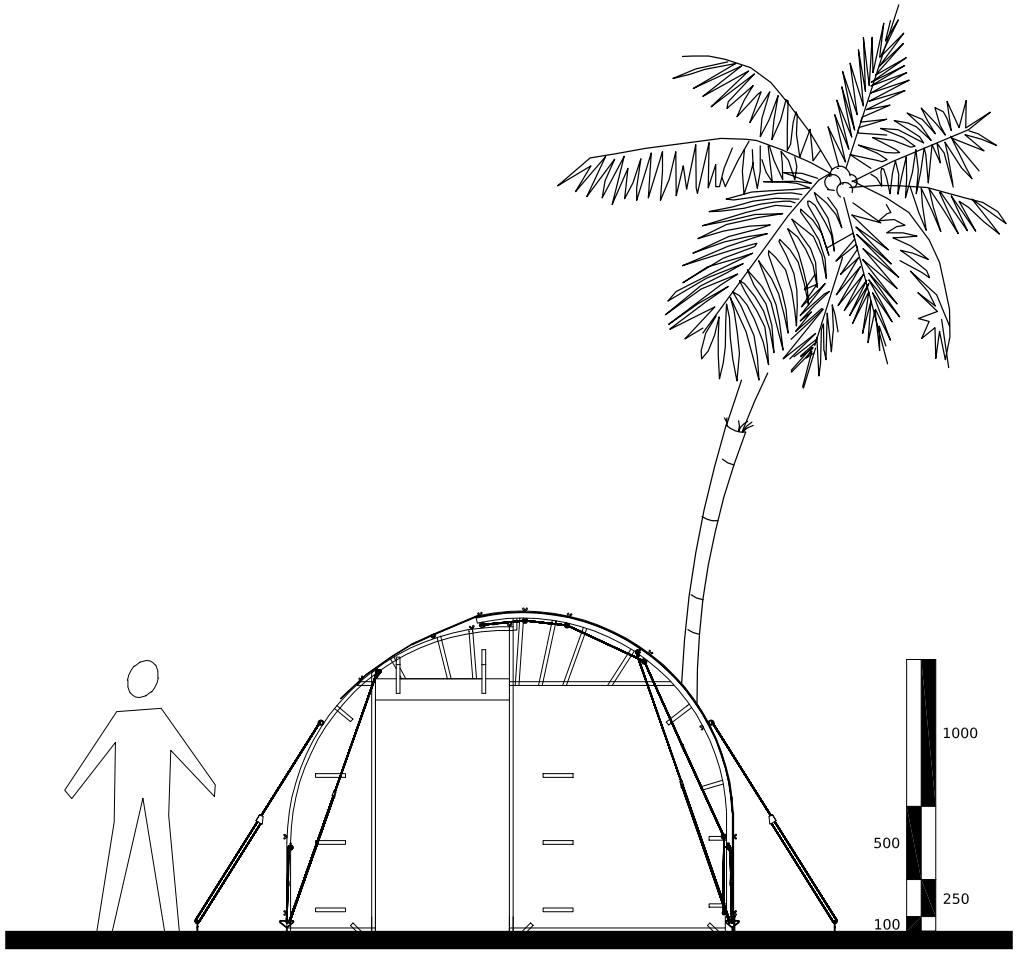
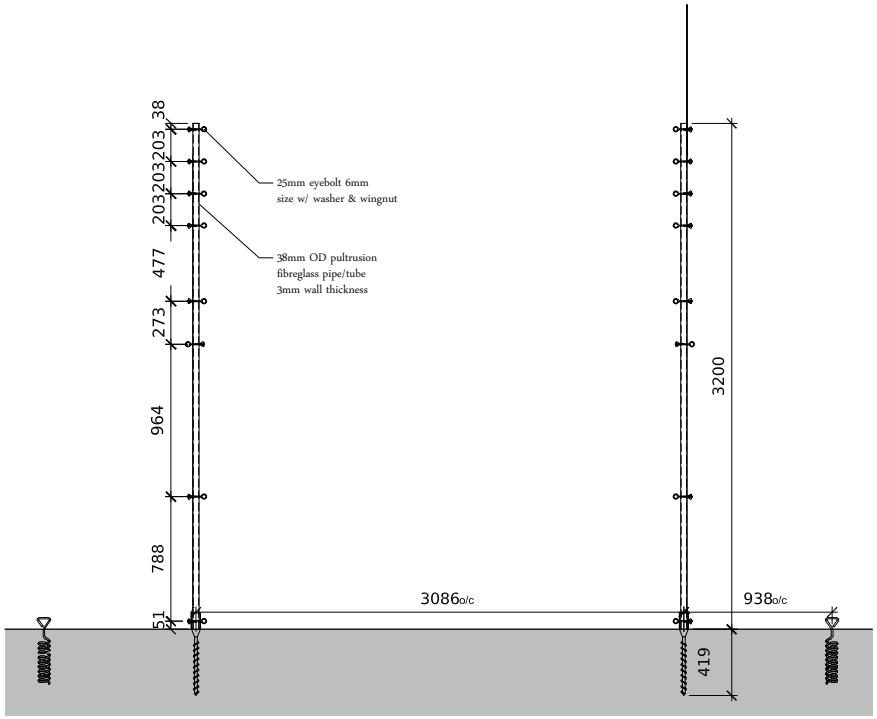


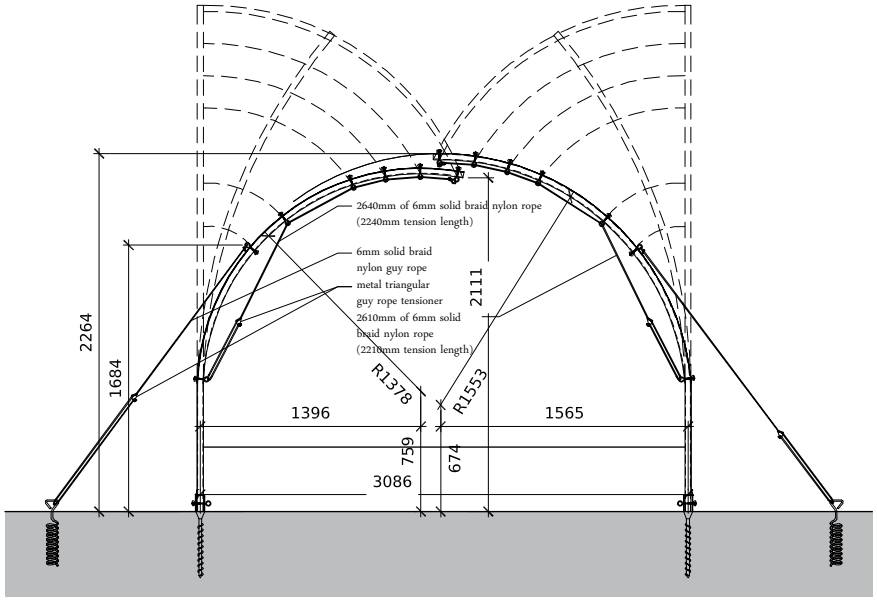

Diagram Elevation 3 (NTS)

E23




Frame Before Bending (NTS)

E24

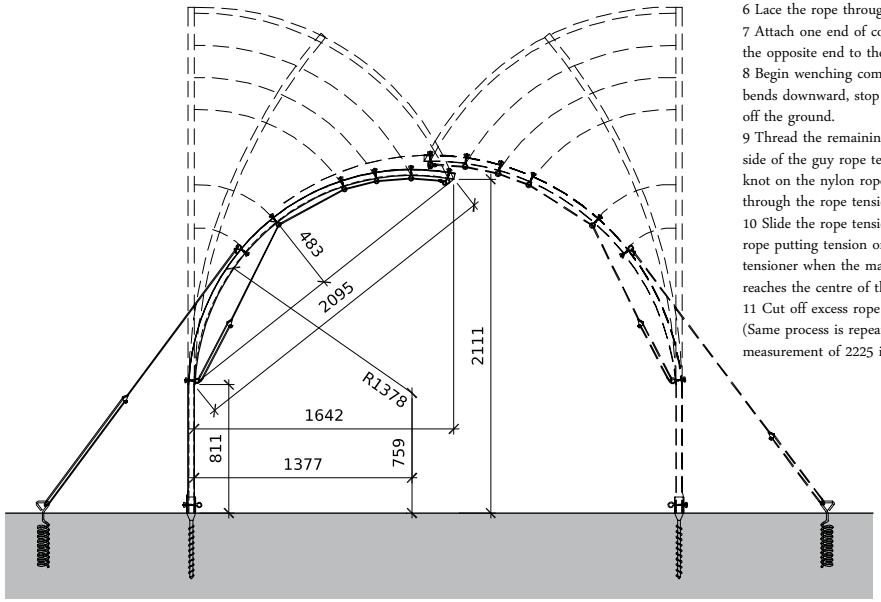



Frame After Bending (NTS)

E25

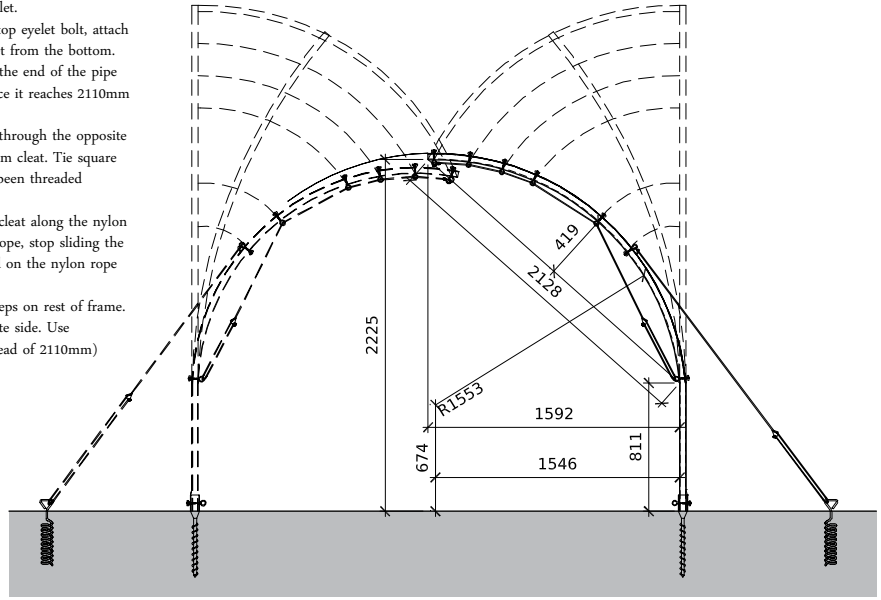
Lacing interior tension rope:

1 Use an anchor hitch knot to affix one end of the nylon rope provided to the top eyelet bolt.
2 Fish the frame tensioning rope through eyelets after lateral bracing and horizontal ropes have been laced.
3 Taunt rope and place a measure 2240mm after the hitch knot attached to the eyelet, place a mark there.
4 Thread nylon rope through all eyelets except the last one.
5 Before lacing through the last hole, thread the nylon rope through one side of guy rope tensioner or clam cleat.
6 Lace the rope through the last eyelet.
7 Attach one end of come-along to top eyelet bolt, attach the opposite end to the second eyelet from the bottom.
8 Begin wenching come-along until the end of the pipe bends downward, stop wenching once it reaches 2110mm off the ground.
9 Thread the remaining nylon rope through the opposite side of the guy rope tensioner or clam cleat. Tie square knot on the nylon rope after it has been threaded through the rope tensioner.
10 Slide the rope tensioner or clam cleat along the nylon rope putting tension on this nylon rope, stop sliding the tensioner when the mark you placed on the nylon rope reaches the centre of the eyelet.
11 Cut off excess rope and repeat steps on rest of frame. (Same process is repeated on opposite side. Use measurement of 2225 in step 8, instead of 2110mm)



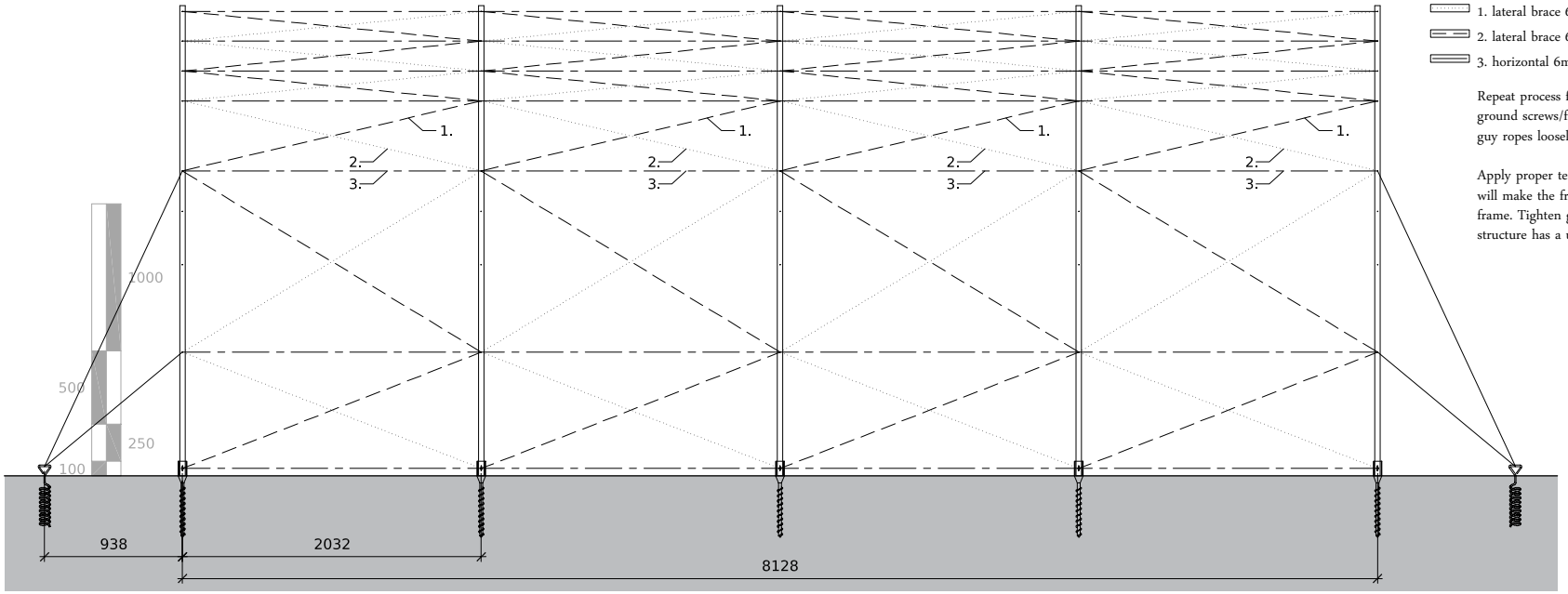

Bending Left Side (NTS)

E26




Bending Right Side (NTS)

E27



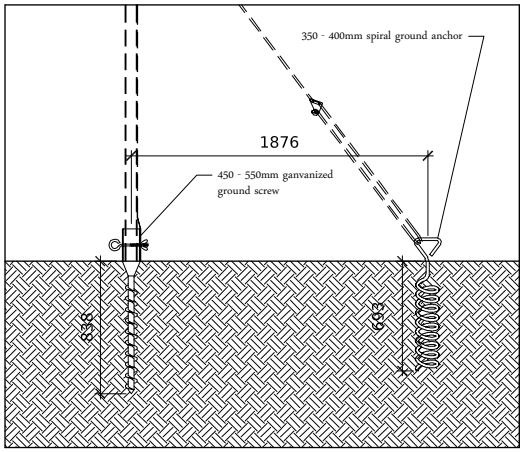

1. lateral brace 6mm solid braid nylon rope, lace first
2. lateral brace 6mm solid braid nylon rope, lace second
3. horizontal 6mm solid braid nylon rope, lace third

Repeat process for each section. Attach frame poles to ground screws/fibreglass or bamboo ground anchor. Fix guy ropes loosely to frame.

Apply proper tension to interior tension ropes that will make the frame curve. Repeat process for each frame. Tighten guy ropes. Adjust all ropes to ensure the structure has a uniform tension and shape.

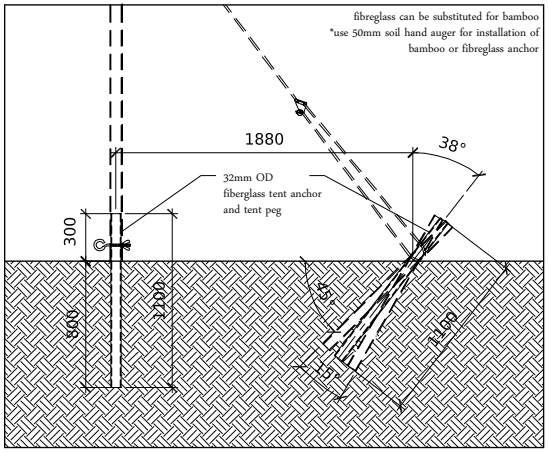
## Lateral Brace Rope Lacing Instructions (NTS)

E28



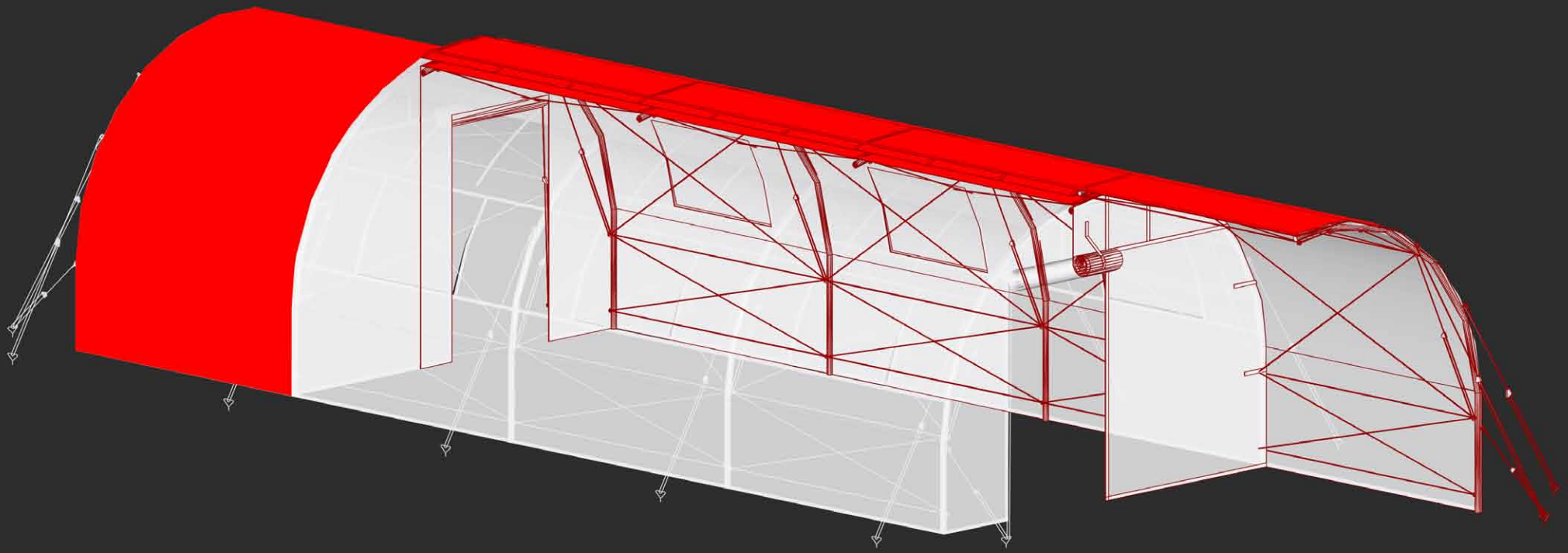

Frame Anchor and Peg Detail 1 (NTS)

E29




Frame Anchor and Peg Detail 2 (NTS)

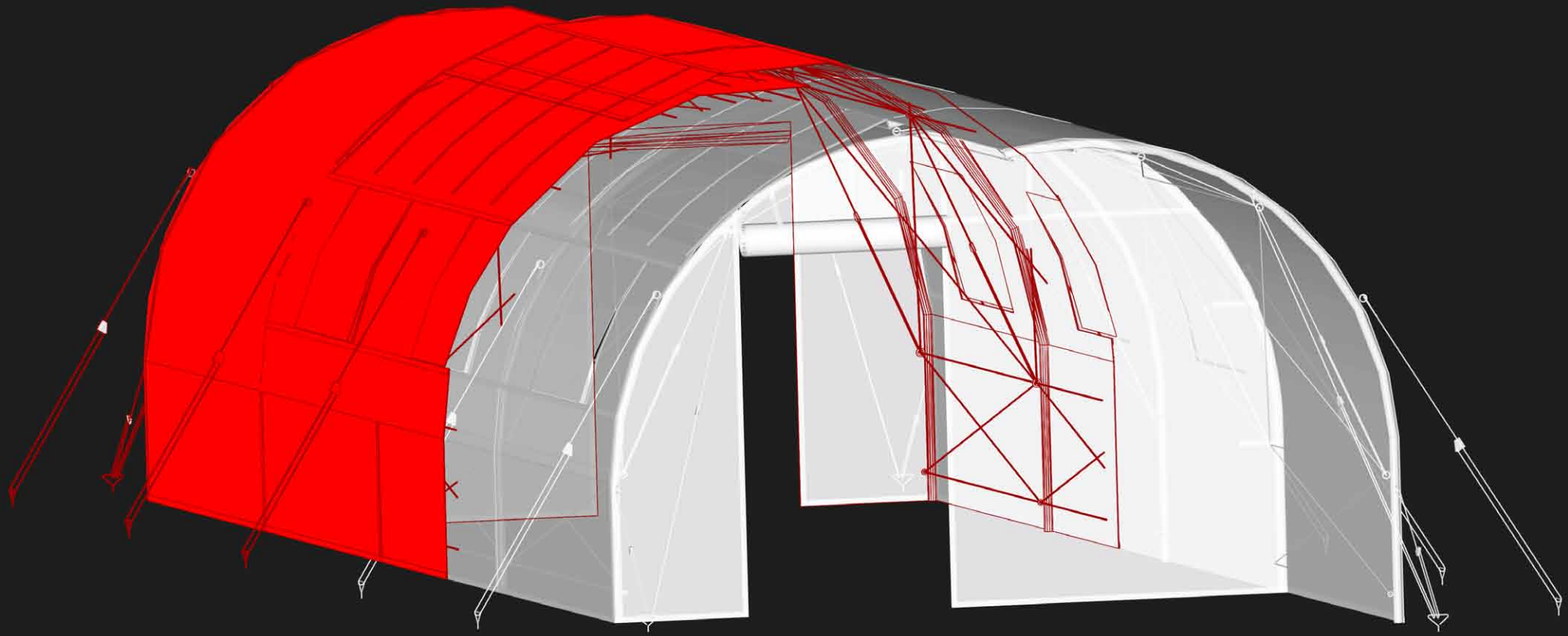
E30



## Diagramatic Section 1

E31

Images E31 & E32 (both pages)
Conceptual 3D sections showing
both the interior and exterior
simultaneously.



Diagramatic Section 2

E32


E33

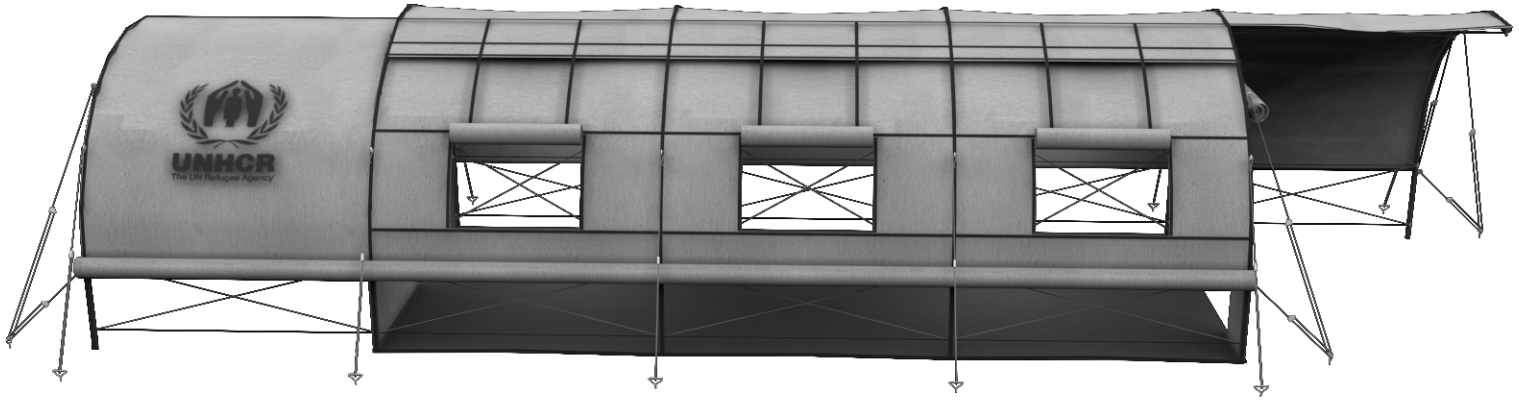
## BWSTR Series Shelter

(ventilation flaps down)

E33, E34, E35


E34

E35




E36

## BWSTR Series Shelter

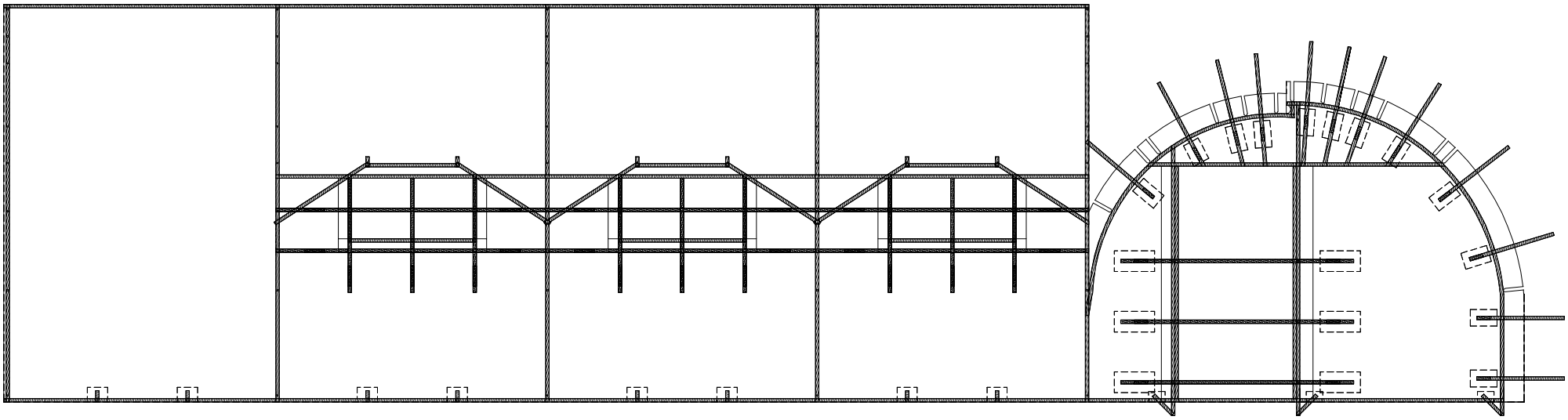
(ventilation flaps up)

E36, E37, E38

E37

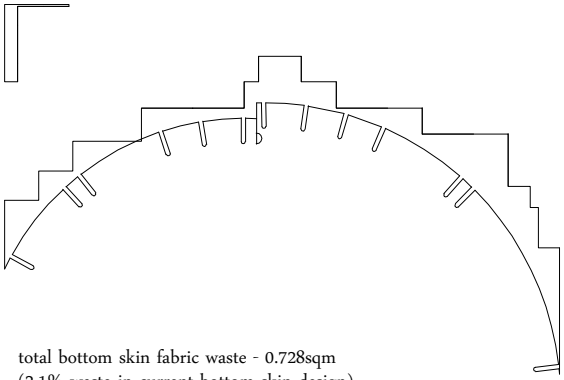

E38

# BWSTR Series Fabrication Drawings
(All measurements presented in mm)

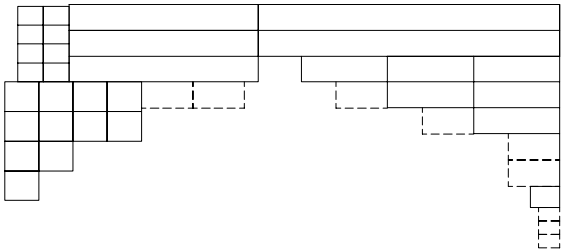


## Total sewn on strapping bottm skin (interior and exterior overlays)
E39

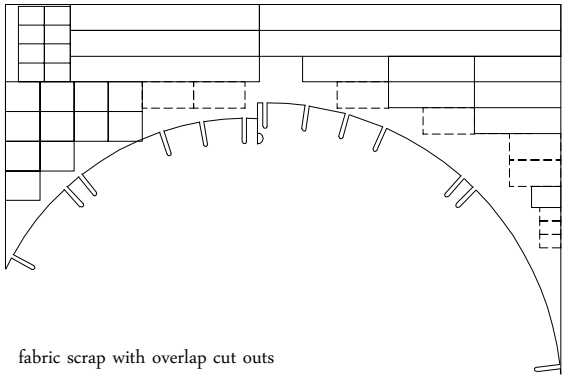
Images E39 - E50 (following pages)
These images are the drawings required to manufacture BWSTR Series emergency shelter system. E39 - E43 are the drawings required to produce the bottom skin. Drawings E41 - E43 show where nylon strapping must be sewn to the fabric skin. Without this strapping sewn to the skin, there would be no way to close openings on the bottom skin.



total bottom skin fabric waste - 0.728sqm
(2.1% waste in current bottom skin design)



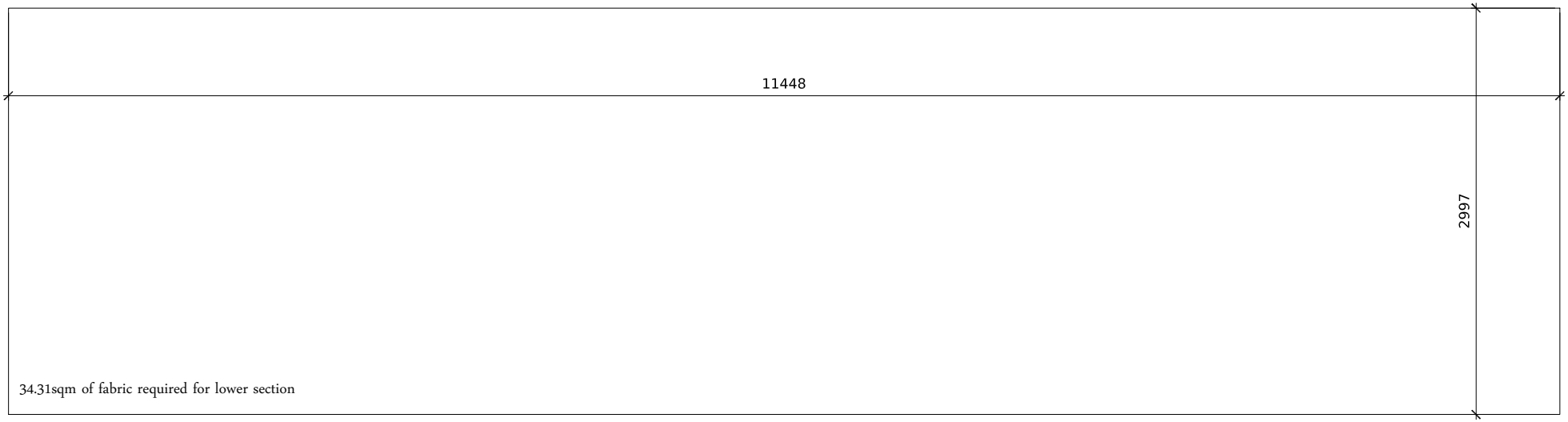
overlap required for windows, doors
and reinforcement



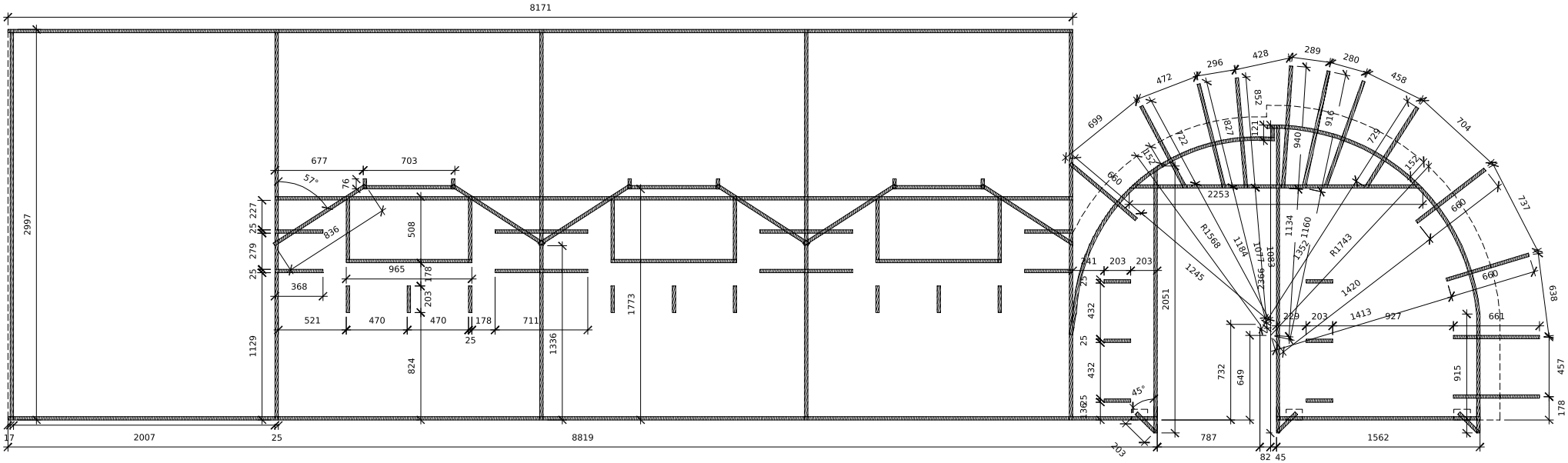
fabric scrap with overlap cut outs

# Total skin material used, excess shown (lower skin)

E40

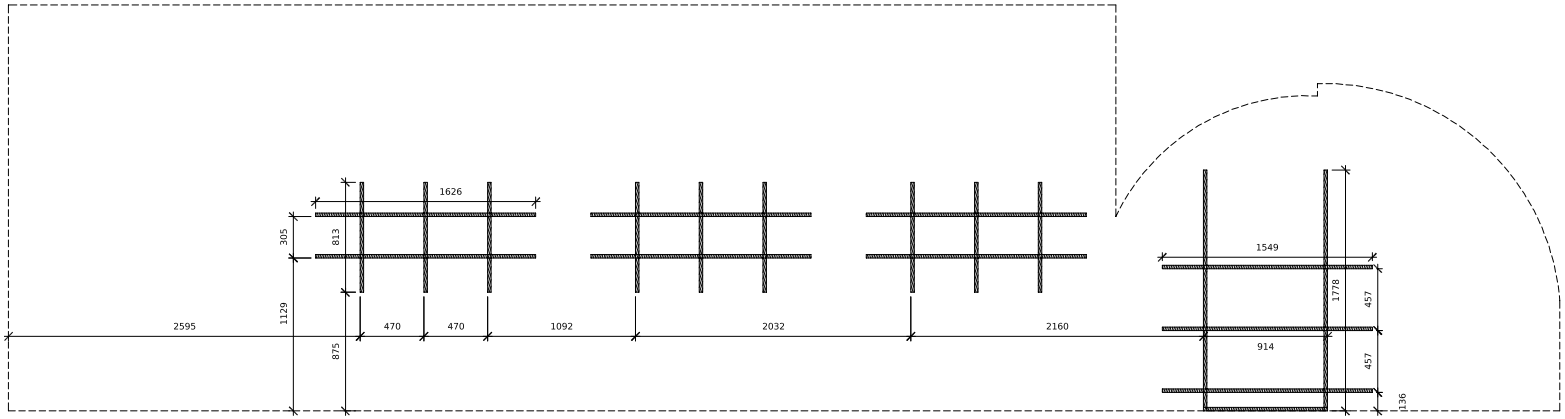



34.31sqm of fabric required for lower section

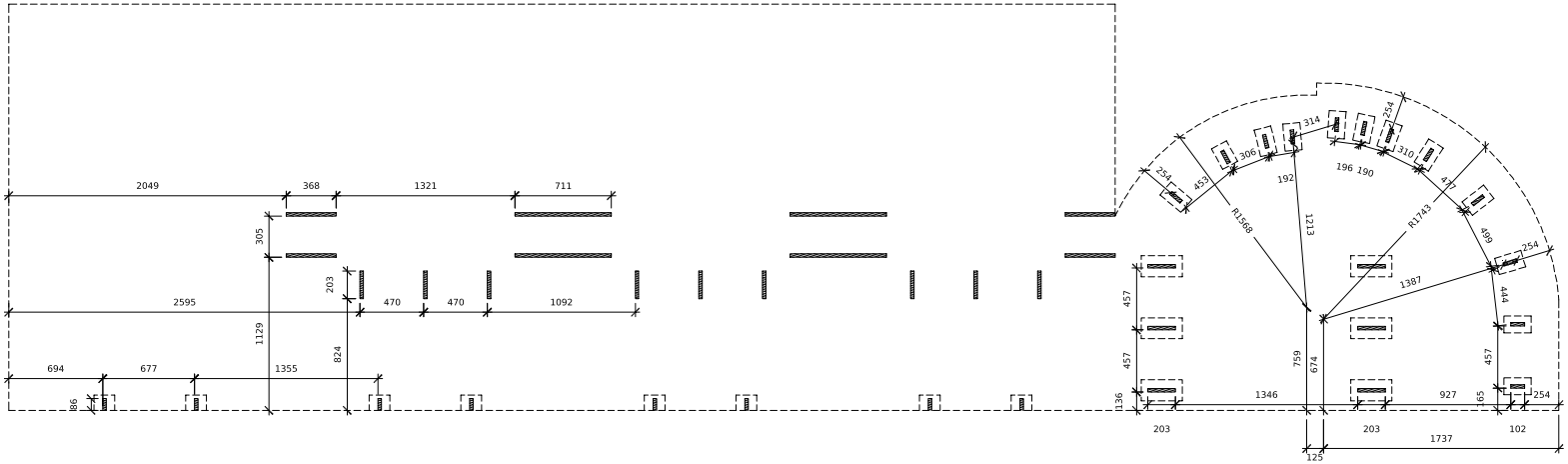



# Sewn exterior strapping (bottom skin)

E41

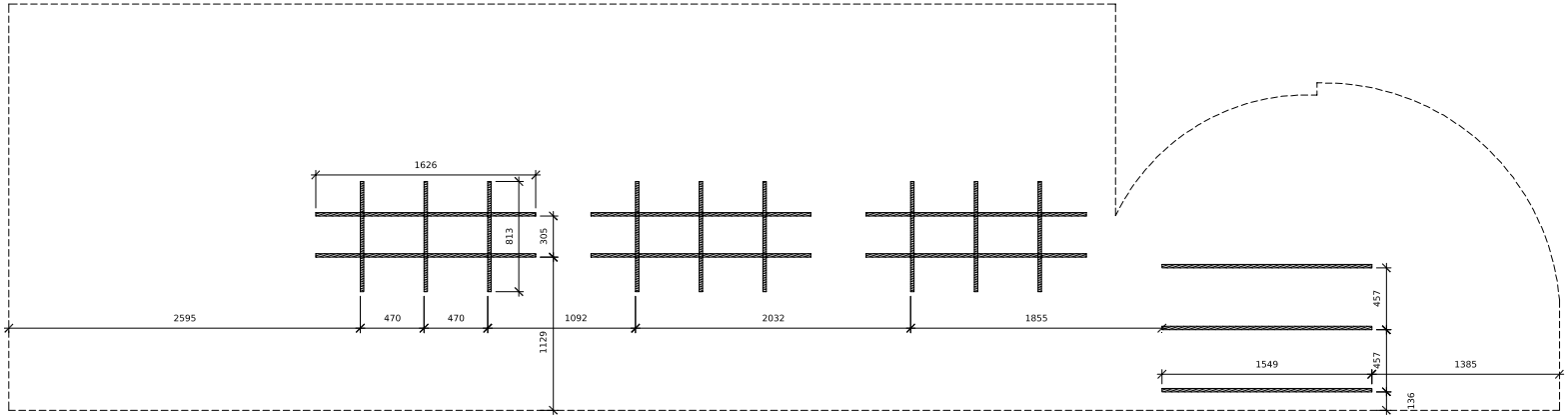



Exterior window and door strapping (bottom)



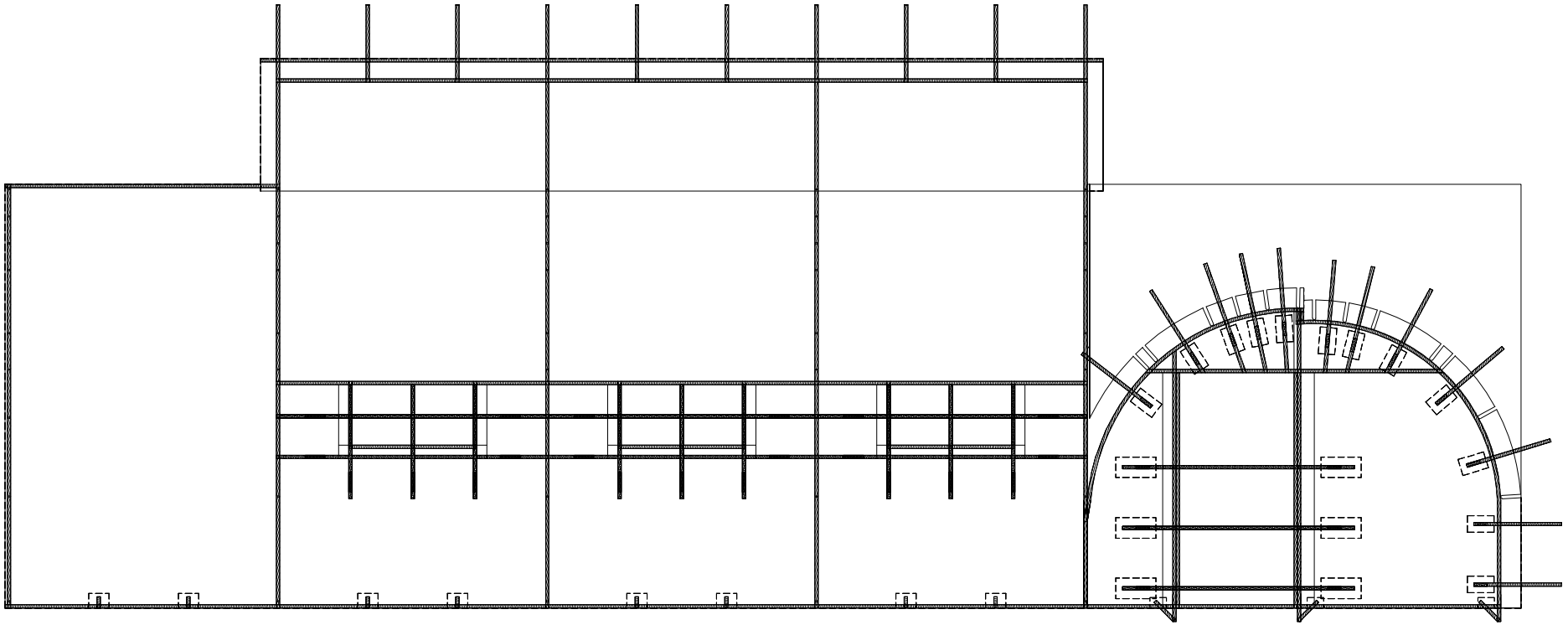

Sewn interior strapping (bottom)

E42




Interior window and door strapping (bottom)

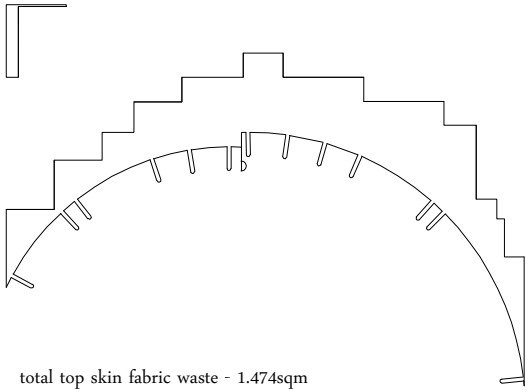
E43



# Total sewn on strapping top skin (interior and exterior overlays)

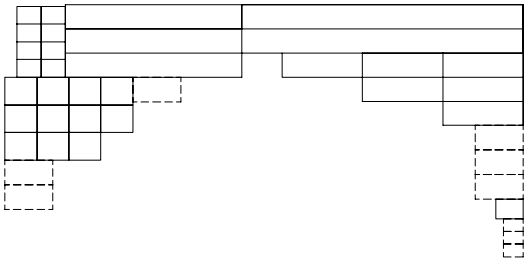
E44

E44 - E49 are the drawings required to produce the top skin. Drawings E46 - E49 show where nylon strapping must be sewn to the fabric skin. Without this strapping sewn to the skin, there would be no way to close openings on the top skin.

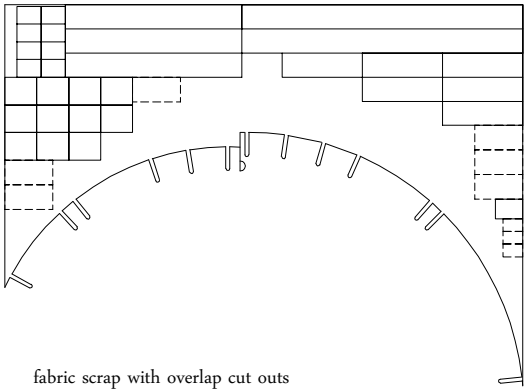


total top skin fabric waste - 1.474sqm
(3.4% waste in current top skin design)

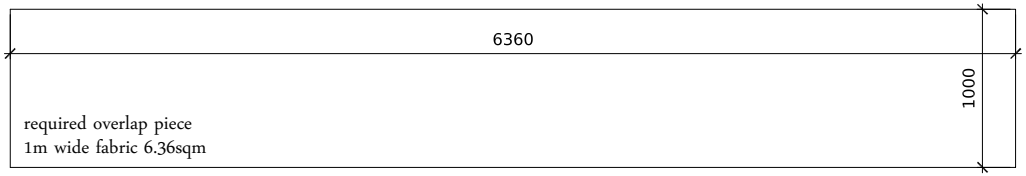
total fabric waste - 2.202sqm
(2.8% waste total in current skin design)



overlap required for windows, doors
and reinforcement



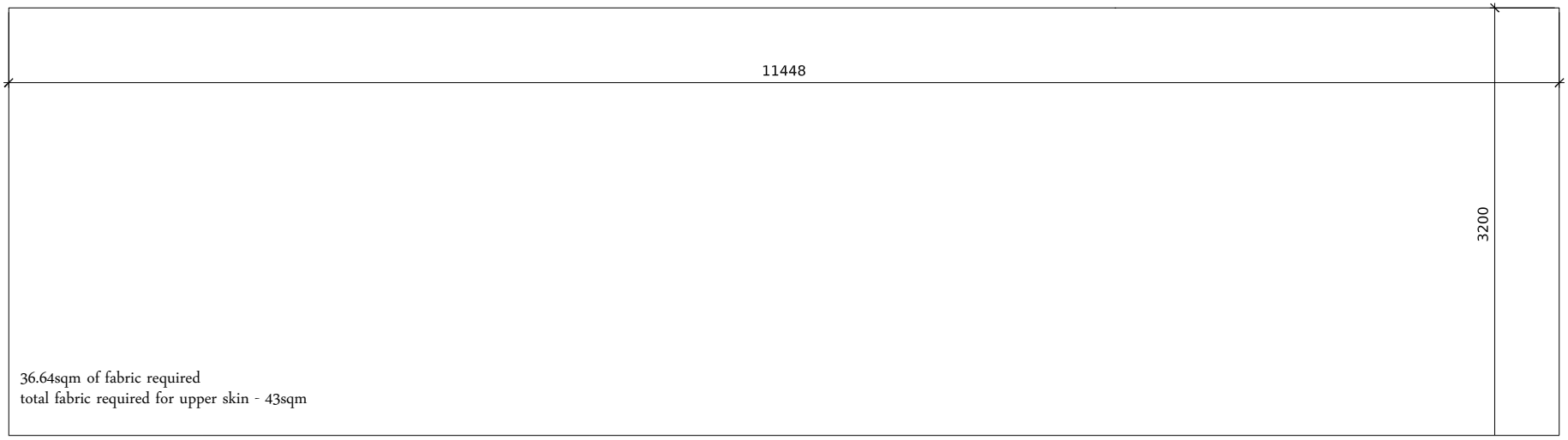
fabric scrap with overlap cut outs



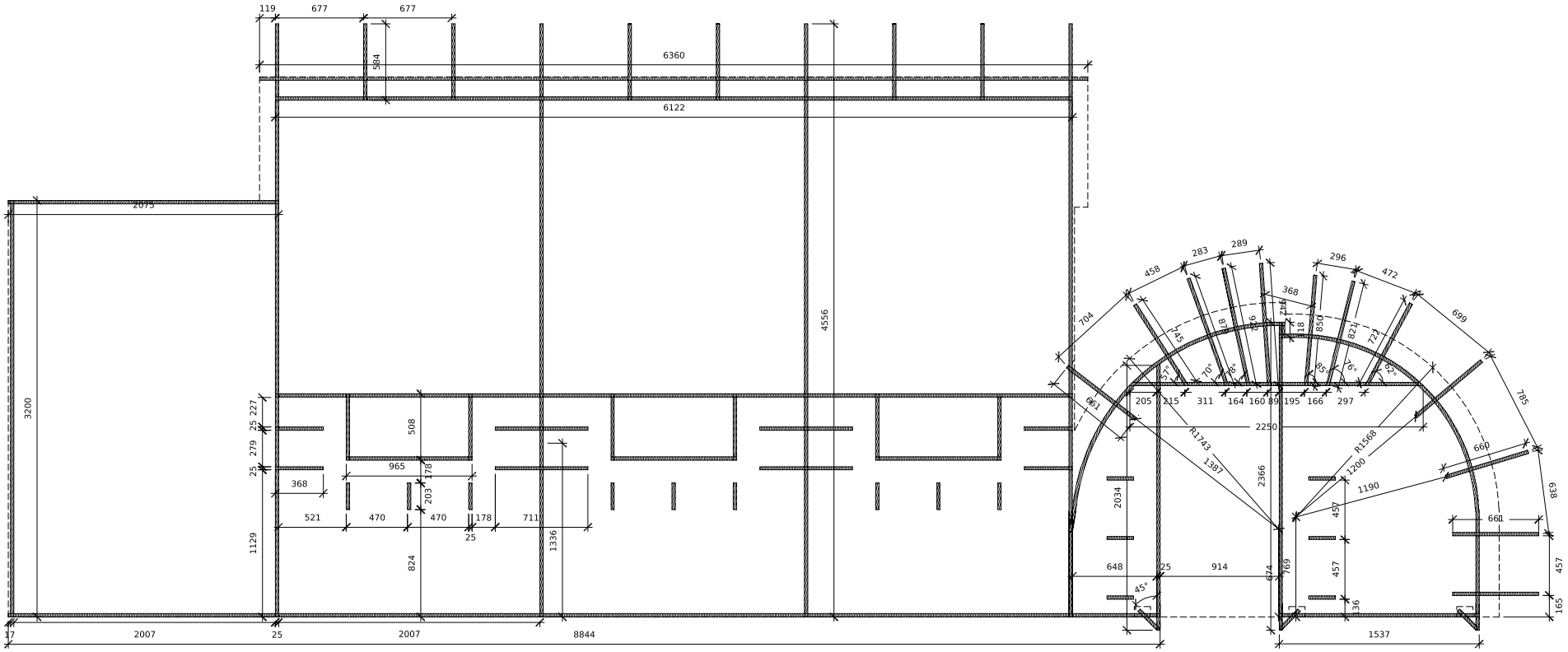

required overlap piece
1m wide fabric 6.36sqm

# Total skin material used, excess shown (top skin)

E45

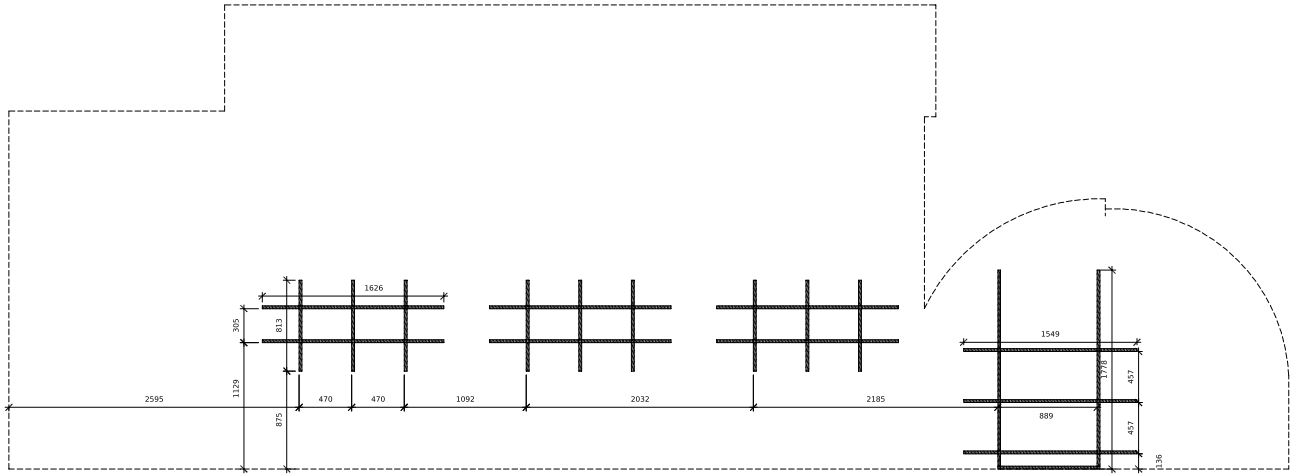



36.64sqm of fabric required
total fabric required for upper skin - 43sqm



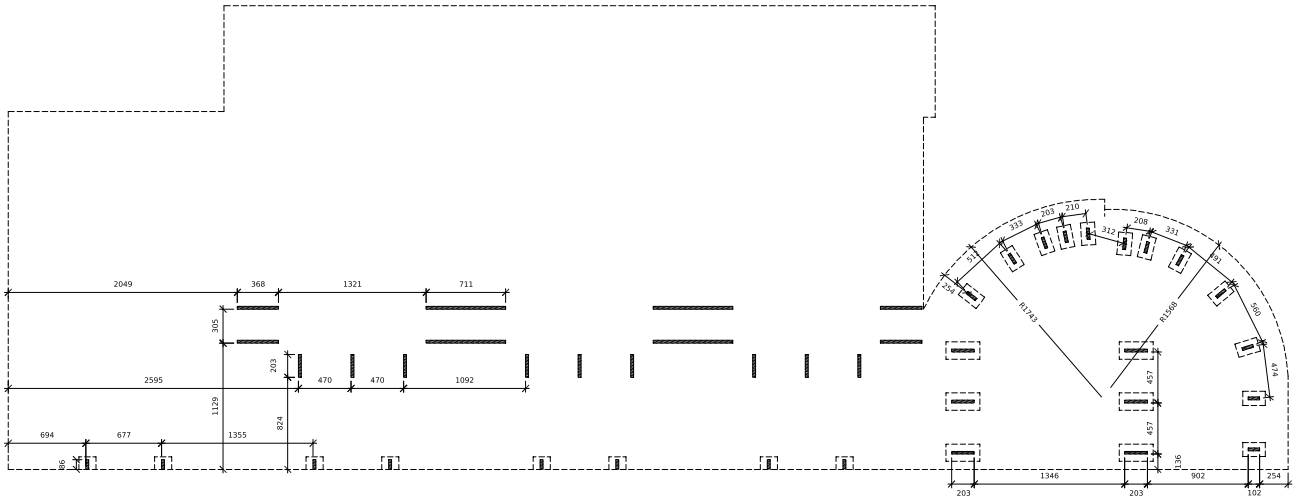

# Sewn exterior strapping (top skin)

E46



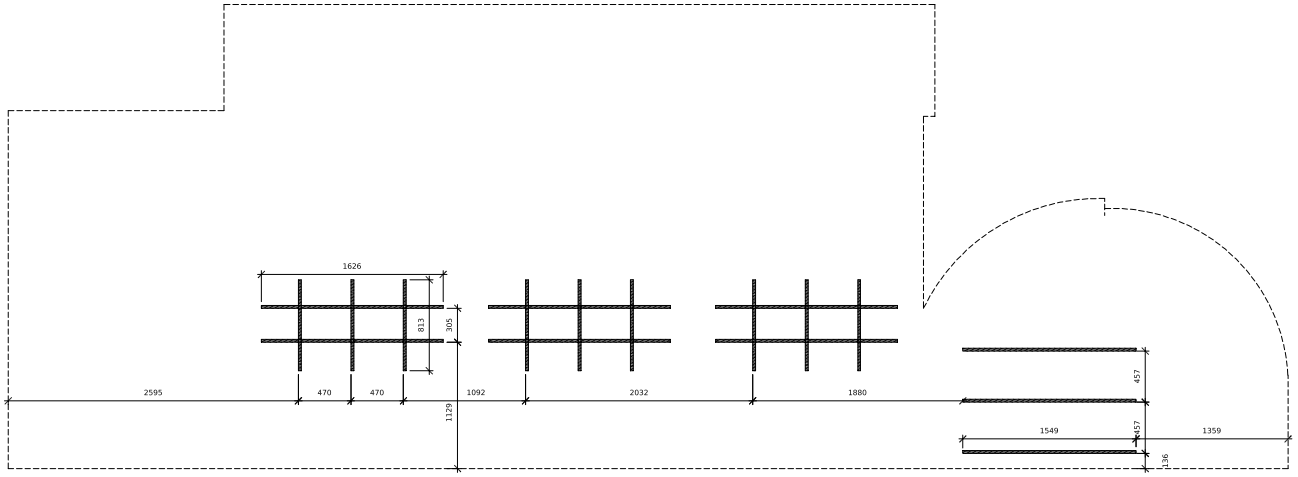

Exterior window and door strapping (top)

E47



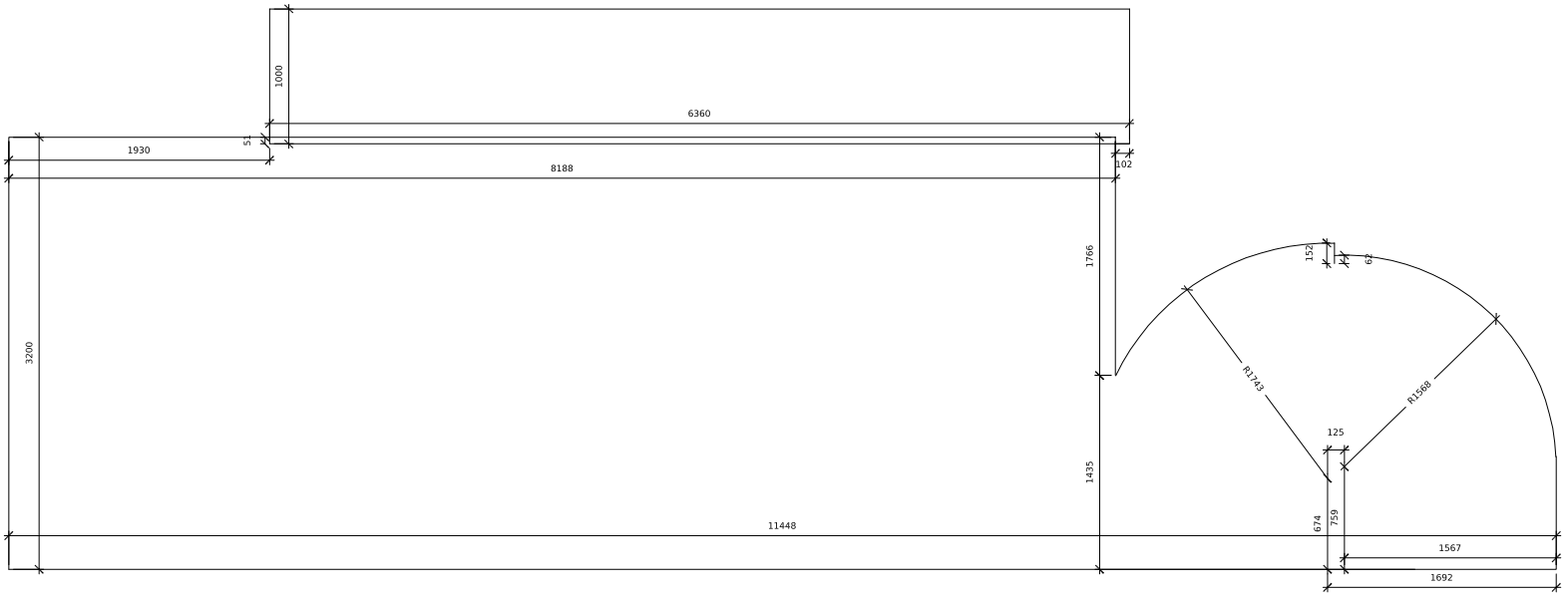

Sewn interior strapping (top)

E48




Interior window and door strapping (top)

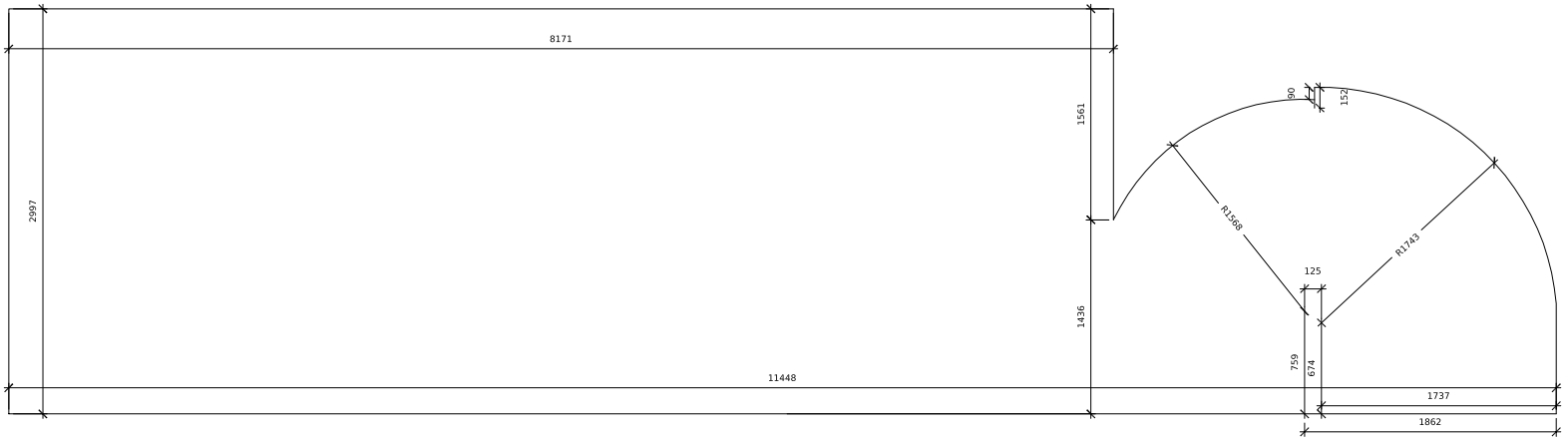
E49




# Upper and Lower Skin Fabrication Drawings

E50

E50 is the drawing that is required for the fabrication of the skin layer using a CAD operated fabric cutting table.




E51

Image E51 (above)
Hypothetical camp using BWSTR shelters in Darfur, Sudan.


Image E52 (above) & E53 (opposite)
Hypothetical camp using BWSTR
shelters in Darfur, Sudan.


UNHCR
123
E53

E54

Image E54 (above) & E55 (opposite)
Hypothetical living conditions
inside a BWSTR shelter.


E55

# Quantitative Analysis

The next several pages will focus on material quantity and cost, shelter comparisons, shipment configurations, and cost comparison: reuse vs. new.

The chart in Fig. 5.02 (right) showcases the different material types used for the shelter in this thesis. Selecting materials for the BWSTR Series shelter was based on high strength-to-weight ratios. Synthetic materials like PVC-coated fabrics, fibreglass pipes, and nylon rope have these characteristics. Several options are presented with different skin and frame material options. Some of these materials are better suited to different climates and regions.

This chart (Fig. 5.02), is a menu that can create custom shelters to suit the needs of humanitarian organizations.

| BWSTR Series Cost Analysis | Unit | Unit Cost (USD) | Quantity | Cost (USD) | Unit Wgt (KG) | Total Weight (KG) |
|---|---|---|---|---|---|---|
| **Shelter Material** | | | | | | |
| **Frame** | | | | | | |
| 38mm OD pultrusion frp | m | 1.42 | 32 | 45.44 | 0.398 | 12.74 |
| 36mm OD tonkin bamboo | m | 0.03 | 32 | 0.96 | 0.188 | 6.02 |
| 36mm OD moso bamboo | m | 0.01 | 32 | 0.32 | 0.2 | 6.40 |
| **Skin** | | | | | | |
| 800gsm 1000D*1000D PVC coated polyester | sqm | 1.4 | 77.31 | 108.23 | 0.8 | 61.85 |
| 560gsm 600d*600D PVC coated polyester | sqm | 1.2 | 77.31 | 92.77 | 0.56 | 43.29 |
| 700gsm 100% cotton canvas skin | sqm | 3.64 | 77.31 | 281.41 | 0.7 | 54.12 |
| 400gsm 100% cotton canvas skin | sqm | 1.66 | 77.31 | 128.33 | 0.4 | 30.92 |
| 300gsm 100% cotton canvas skin | sqm | 1.44 | 77.31 | 111.33 | 0.3 | 23.19 |
| 400gsm 35%cotton/65%polyester canvas skin | sqm | 1.24 | 77.31 | 95.86 | 0.4 | 30.92 |
| 300gsm 35%cotton/65%polyester canvas skin | sqm | 1.06 | 77.31 | 81.95 | 0.3 | 23.19 |
| 160gsm 100%oxford nylon | sqm | 0.67 | 77.31 | 51.80 | 0.16 | 12.37 |
| 60gsm polyethylene tarp | sqm | 0.05 | 77.31 | 3.87 | 0.06 | 4.64 |
| **Bracing/Reinforcement** | | | | | | |
| 900D polypropylene strapping | m | 0.04 | 296 | 11.84 | 0.017 | 5.03 |
| 6mm solid braid nylon rope | m | 0.04 | 374 | 14.96 | 0.017 | 6.36 |
| **Anchorage** | | | | | | |
| 550mm galvanized ground screws | pc | 3.29 | 10 | 32.90 | 1.8 | 18.00 |
| 400mm spiral ground anchor | pc | 0.35 | 14 | 4.90 | 0.72 | 10.08 |
| 300mm galvanized tent pegs | pc | 0.05 | 10 | 0.50 | 0.1 | 1.00 |
| 600mm moso bamboo anchor | m | 0.01 | 7.32 | 0.07 | 0.5 | 3.66 |
| 600mm pultrusio frp anchor | m | 1.42 | 7.32 | 10.39 | 0.2 | 1.46 |
| **Hardware** | | | | | | |
| 25mm 316 stainless eyebolts 6mm (w/ wing) | pc | 0.1 | 80 | 8.00 | 0.075 | 6.00 |
| 25mm polished iron eyebolts 6mm (w/ wing) | pc | 0.03 | 80 | 2.40 | 0.075 | 6.00 |
| 25mm D rings | pc | 0.01 | 432 | 4.32 | 0.017 | 7.34 |
| 316 stainless clam rope cleat | pc | 0.1 | 14 | 1.40 | 0.1 | 1.40 |
| metal guy rope tensioner | pc | 0.25 | 14 | 3.50 | 0.027 | 0.38 |
| **Ground Cover** | | | | | | |
| 60gsm polyethylene tarp | sqm | 0.05 | 17.97 | 0.90 | 0.06 | 1.08 |
| **Security Feature** | | | | | | |
| 50mmx50mm galvanized wire fencing | sqm | 0.18 | 33.44 | 6.02 | 0.26 | 8.69 |
| 75mmx75mm polyethylene netting | sqm | 1.19 | 33.44 | 39.79 | 0.41 | 13.71 |
| **Optional Tools** | | | | 0.00 | | 0.00 |
| 50mm dia. 1m depth soil auger | pc | 100 | 1 | 100.00 | 2 | 2.00 |
| 25L HDPE pail | pc | 2 | 1.5 | 3.00 | 0.8 | 1.20 |
| 60L HDPE barrel w/ lid | pc | 10.16 | 1 | 10.16 | 3.4 | 3.40 |
| 1kg hand-held sledgehammer | pc | 1 | 1 | 1.00 | 1 | 1.00 |
| 18mm utility knife | pc | 1 | 0.3 | 0.30 | 0.07 | 0.02 |
| 250mm plier | pc | 0.9 | 2 | 1.80 | 0.36 | 0.72 |

Fig. 5.02 (both pages)
The amount of material needed to manufacture various models of BWSTR Series emergency shelters.

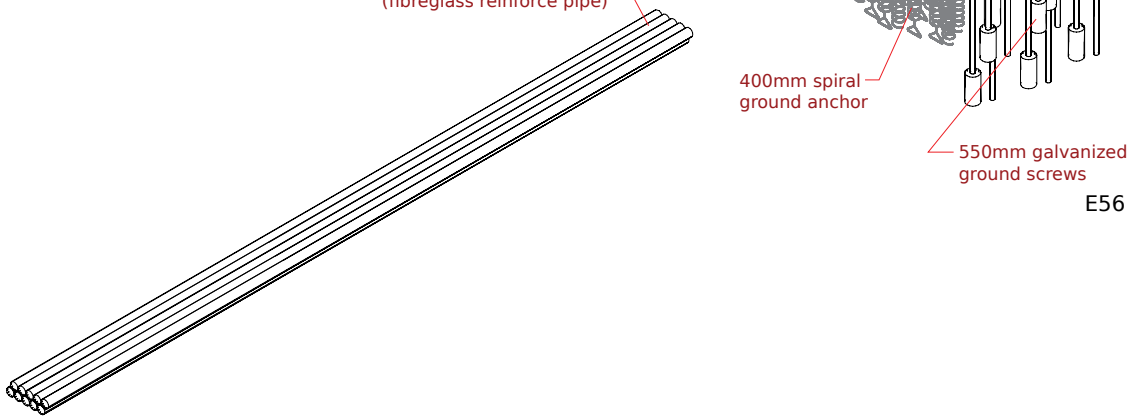
| | BWSTR 01s<br>Optimum 1 | BWSTR 02s<br>Optimum 2 | BWSTR 03c<br>Canvas 1 | BWSTR 04c<br>Canvas 2 | BWSTR 05c<br>Canvas 3 | BWSTR 06n<br>Nylon 1 | BWSTR 07n<br>Nylon 2 | BWSTR 08p<br>Poly 1 | BWSTR 09r<br>Regional 1 | BWSTR 10r<br>Regional 2 |
|---|---|---|---|---|---|---|---|---|---|---|
| | x | x | x | x | x | x | x | x | | |
| | | | | | | | | | | |
| | | | | | | | | | x | x |
| | x | | | | | | | | | |
| | | x | | | | | | | | |
| | | | x | | | | | | | |
| | | | | | | | | | | |
| | | | | x | | | | | | |
| | | | | | | | | | | |
| | | | | | x | | | | | |
| | | | | | | x | x | | | |
| | | | | | | | | x | x | x |
| | x | x | x | x | x | x | x | | | |
| | x | x | x | x | x | x | x | x | x | x |
| | x | x | x | x | x | x | | | | |
| | x | x | x | x | x | x | | | | |
| | x | x | x | x | x | x | | | | |
| | | | | | | | | | x | x |
| | | | | | | | x | x | | |
| | x | x | x | | | | | | | |
| | | | | x | x | x | x | x | | |
| | x | x | x | x | x | x | x | | | |
| | x | x | x | | | | | | | |
| | | | | x | x | x | x | x | x | x |
| | x | x | x | x | x | x | x | | | |
| | | | | | | x | x | x | | |
| | | | | | | | | | | |
| | | | | | | | x | x | x | x |
| | x | x | x | x | x | x | x | x | x | |
| | x | x | x | x | x | x | x | x | x | |
| | x | x | x | x | x | x | x | x | x | |
| | x | x | x | x | x | x | x | x | x | |
| | x | x | x | x | x | x | x | x | x | |

Fig. 5.02

| BWSTR Cost Analysis Summary | BWSTR 01s Optimum 1 | BWSTR 02s Optimum 2 | BWSTR 03c Canvas 1 | BWSTR 04c Canvas 2 | BWSTR 05c Canvas 3 | BWSTR 06n Nylon 1 | BWSTR 07n Nylon 2 | BWSTR 08p Poly 1 | BWSTR 09r Regional 1 | BWSTR 10r Regional 2 |
|---|---|---|---|---|---|---|---|---|---|---|
| Total Cost | $249.65 | $234.19 | $422.83 | $249.24 | $219.87 | $195.74 | $167.83 | $106.84 | $39.44 | $23.18 |
| Total Weight | 137.22 | 118.66 | 129.49 | 97.54 | 97.54 | 122.72 | 95.10 | 47.15 | 58.97 | 50.63 |
| 30% Manufacturing Cost | $324.55 | $304.45 | $549.67 | $324.02 | $285.83 | $254.46 | $218.18 | $138.89 | $51.27 | $30.13 |
| 50% Manufacturing Cost | $374.48 | $351.29 | $634.24 | $373.87 | $329.80 | $293.60 | $251.74 | $160.26 | $59.16 | $34.77 |
| 100% Manufacturing Cost | $499.31 | $468.38 | $845.65 | $498.49 | $439.73 | $391.47 | $335.66 | $213.68 | $78.88 | $46.36 |
| Number in 6 m ISO container | 158 | 183 | 168 | 192 | 192 | 177 | 192 | 192 | 192 | 350 |
| People sheltered per container | 792 | 915 | 839 | 960 | 960 | 885 | 960 | 960 | 960 | 1,750 |
| Cost per 6 m container (50% man. Cost) | $59,295 | $64,320 | $106,422 | $71,783 | $63,322 | $51,982 | $48,335 | $30,770 | $11,358 | $12,170 |
| Number in 12 m ISO container | 195 | 226 | 207 | 275 | 275 | 218 | 282 | 408 | 408 | 529 |
| People sheltered per container | 976 | 1,128 | 1,034 | 1,373 | 1,373 | 1,091 | 1,408 | 2,040 | 2,040 | 2,645 |
| Cost per 12 m container (50% man. Cost) | $73,085 | $79,279 | $131,172 | $102,647 | $90,548 | $64,072 | $70,890 | $65,386 | $24,136 | $18,391 |

**Fig. 5.03**

Fig. 5.03 is the conclusion of Fig. 5.02. There is a direct comparison between the different predetermined options. Cost and weight are factors that concern humanitarian organizations. Again, these are just suggested models. Shelters can be custom-ordered based on regional needs.



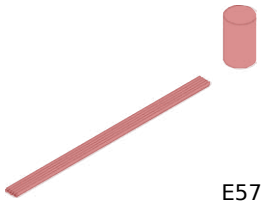

E56

Fig. 5.03 (above)
Several different BWSTR models are compared by cost and weight. A 6 m ISO container can hold 158 – 350 BWSTR Series shelters without being palleted. While a 12 m ISO container can hold 195 – 529 BWSTR Series shelters without being palleted. The fluctuation between these figures is in regards to the weight differences between each shelter model.

Image E56 (bottom left)
All of these BWSTR components (except frame) fit inside a 60L plastic drum. The plastic drum can be used to store food or other items afterwards.

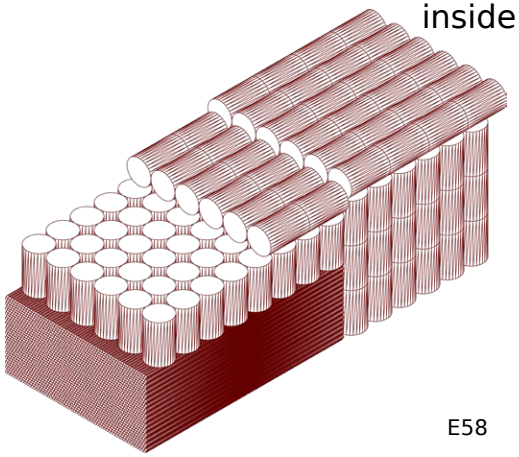
Image E57 - E61 (opposite)
Scale drawings as a visual aid for shelter ISO container shipment. This packing arrangement does not include stacking on pallets.

One BWSTR shelter at scale.

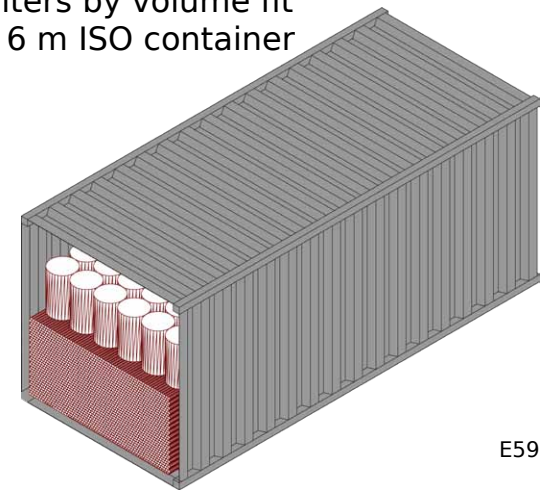


E57

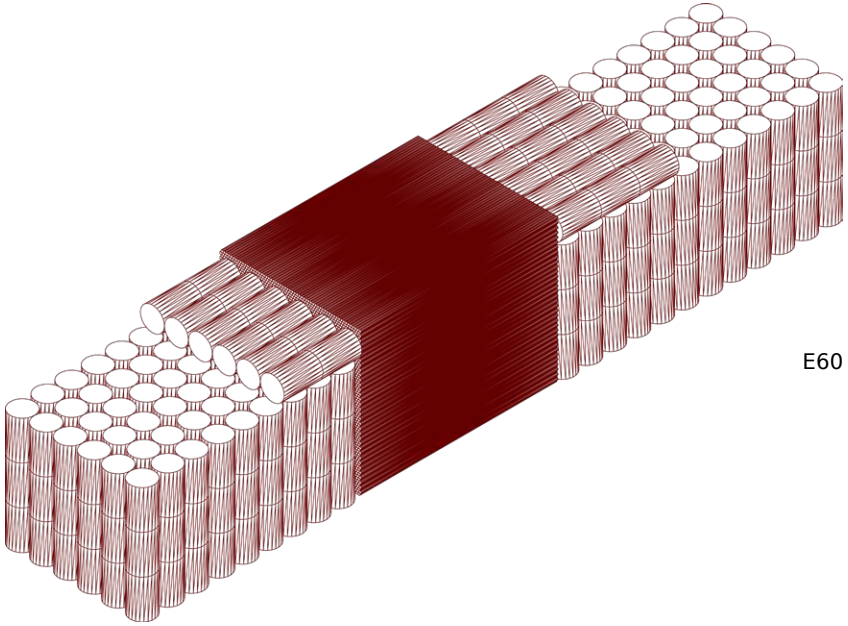
192 shelters by volume fit inside a 6 m ISO container



E58

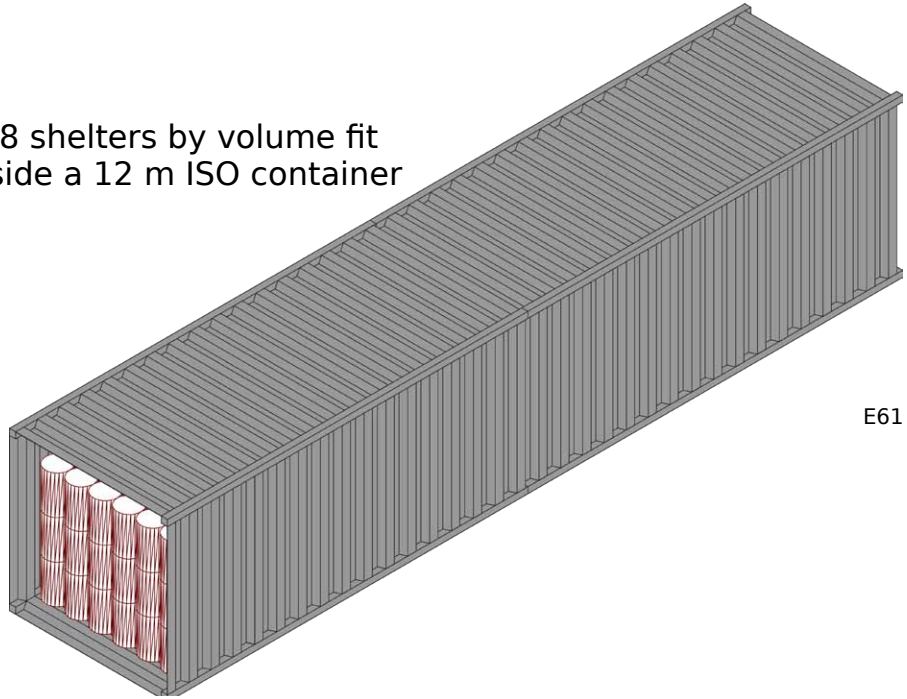


E59



E60

408 shelters by volume fit inside a 12 m ISO container



E61

## Tent cost comparison

(Single Family vs. Multi-Family)

| | Frame Tent (UNHCR) | Tunnel Tent (Western Wall) | Dome Tent (Shelter Systems) | 1945 Style Army Tent (used & new) | LWET[4] Version 4.1 (UNHCR/ IFRC) | Dbl Fly Ridge Tent (UNHCR/ IFRC) | Thesis Optimum 1 Design (BWSTR 01s) | Thesis Canvas 3 Design (BWSTR 05c) | Thesis Poly Tarp 1 Design (BWSTR 08p) | Large UN Frame Tent | Military GP Medium Tent | MDM Relief Tent |
|---|---|---|---|---|---|---|---|---|---|---|---|---|
| Single Family Tent | X | X | X | X | X | X | X | X | X | | | |
| Multi-Family Tent | | | | | | | | | | X | X | X |
| Listed Cost (uSD) | >$500 | $300 | $400 | $435-975 | $500-1000 | $200 | $375 | $330 | $160 | unknown | $2,760 | $4,956 |
| Material Cost (USD) | unknown | unknown | unknown | unknown | $94 | unknown | $250 | $220 | $107 | unknown | unknown | unknown |
| Cheaper Equivalent (USD) | $500 | $175 | $180 | $230 | $300 | $80 | n/a | n/a | n/a | $800 | unknown | unknown |
| Floor Area (sqm) | 12.0 | 10.0 | 13.8 | 15.9 | 16.0 | 14.0 | 17.9 | 17.9 | 17.9 | 27.5 | 47.6 | 53.5 |
| Vestibule | | X | X | X | X | | X | X | X | | | |
| Vestibule (sqm) | 0.0 | 2.0 | 3.5 | 4.5 | 3.5 | 0.0 | 3.0 | 3.0 | 3.0 | 0.0 | 0.0 | 0.0 |
| Weight (kg) | 117 | 45 | 22 | 60 | 55 | 70 | 137 | 98 | 47 | 200 | 250 | 500 |
| Number of persons[1] | 3.43 | 2.85 | 3.90 | 4.54 | 4.57 | 4.00 | 5.11 | 5.11 | 5.11 | 7.86 | 13.59 | 15.29 |
| Duration expectation (years)[2] | >1 | <1 | <1 | >1 | 1 | 1 | >4 | >2 | 1 | >2 | >2 | >4 |
| Centre Height (meters) | 2.5 | 2.0 | 2.1 | 2.7 | 2.2 | 2.1 | 2.1 | 2.1 | 2.1 | 3.2 | 3.2 | 4.6 |
| Shelter cost per person (USD) | $146 | $105 | $102 | $95-213 | $74 | $50 | **$73** | **$64** | **$31** | $115 | $210 | $331 |
| Interior division cost[3] | $0 | $0 | $0 | $0 | $0 | $0 | $0 | $0 | $0 | $100 | $100 | $100 |
| 2 year shelter use cost (USD) | $750 | $900 | $1,200 | $460 | $600 | $400 | $375 | $330 | $190 | $900 | $2,860 | $5,056 |
| 2 year cost per person (USD) | **$219** | **$316** | **$308** | **$101** | **$131** | **$100** | **$73** | **$65** | **$37** | **$115** | **$210** | **$331** |
| 4 year shelter use cost (USD) | $1,500 | $1,500 | $2,000 | $690 | $1,200 | $800 | $375 | $430 | $220 | $1,400 | $3,660 | $5,056 |
| 4 year cost per person (USD) | **$438** | **$526** | **$513** | **$152** | **$263** | **$200** | **$73** | **$84** | **$43** | **$178** | **$269** | **$331** |
| Total shelters used after 4 years[5] | 3 | 5 | 5 | 3 | 4 | 4 | 1 | 2 | 4 | 2 | 2 | 1 |
| Material type | 420 gsm canvas | 170 gsm polyester | 180 gsm polyester | 330 gsm poly duck | 300 gsm poly duck | 300 gsm poly duck | 800 gsm PVC poly | 300 gsm poly duck | 60 gsm polyethyl. | 460 gsm poly duck | 420 gsm poly duck | 610 gsm PVC vinyl |
| Reusable frame (x-yes,o-maybe) | X | | | X | o | o | X | X | X | X | X | X |
| Reusable skin (x-yes,o-maybe) | o | | | o | | | X | o | | o | o | X |
| Ground cloth | X | X | X | | X | X | X | X | X | | | X |

1 based on 3.5m²/person Sphere Standards
2 shelter durability results from Joseph Ashmore's independent assessment of Haitian relief shelters
3 multi family shelters require interior partitions for privacy reasons
4 LWET – Light Weight Emergency Tent
5 If shelters are replaced at time specified

**Fig. 5.04**

Fig. 5.04 compares total cost per person between humanitarian agency supplied single family tents, multi-family tent shelters, and selected thesis designs. This shows that multi-family shelters may be a more expensive option per person than single family shelters.

Fig. 5.04 (above)
Comparing shelter cost per person, multi-family vs. single family shelters

## Cost comparison

(Tent vs. Thesis vs. Transitional)

| | 4m x 5m Tarp (UNHCR) | Dbl Fly Ridge Tent (UNHCR/ IFRC) | Frame Tent (UNHCR) | LWET[4] Version 4.1 (UNHCR/ IFRC) | Thesis Optimum 1 Design (BWSTR 01s) | Thesis Canvas 3 Design (BWSTR 05c) | Thesis Poly Tarp 1 Design (BWSTR 08p) | 2007 Peru T-shelter (IFRC) | Haiti 2010 OSB Hexayurt (Project Hexayurt) | 2009 Sumatra T-shelter (IFRC) | Haiti 2010 T-shelter (Tearfund) | 2010 Haiti T-shelter (Spanish Red Cross) |
|---|---|---|---|---|---|---|---|---|---|---|---|---|
| Listed Cost (uSD) | **$11** | **$200** | **>$500** | **$500-1000** | **$375** | **$330** | **$160** | **$370** | **$200-500** | **$550** | **$3,000** | **$4,600** |
| Material Cost (USD) | $5 | unknown | unknown | $94 | $250 | $220 | $107 | $250 | $125 | $320 | unknown | $1,850 |
| Cheaper Equivalent (USD) | $1 | $80 | $500 | $300 | n/a | n/a | n/a | n/a | n/a | n/a | n/a | n/a |
| Floor Area (sqm) | 20.0 | 14.0 | 12.0 | 16.0 | 17.9 | 17.9 | 17.9 | 18.0 | 15.0 | 18.0 | 18.0 | 18.0 |
| Vestibule | | | | **X** | **X** | **X** | **X** | | | | **X** | |
| Vestibule (sqm) | 0.0 | 0.0 | 0.0 | 3.5 | 3.0 | 3.0 | 3.0 | 0.0 | 0.0 | 0.0 | 4.5 | 0.0 |
| Weight (kg) | **2** | **70** | **117** | **55** | **137** | **98** | **47** | **>300** | **325** | **512** | **693** | **290[3]** |
| Number of persons[1] | 5.71 | 4.00 | 3.43 | 4.57 | 5.11 | 5.11 | 5.11 | 5.14 | 4.29 | 5.14 | 5.14 | 5.14 |
| Duration expectation (years)[2] | **<1** | **1** | **>1** | **1** | **>4** | **>2** | **1** | **1** | **>1** | **1** | **>1** | **2** |
| Centre Height (meters) | unknown | 2.1 | 2.5 | 2.2 | 2.1 | 2.1 | 2.1 | 2.0 | 2.4 | 2.3 | 3.1 | 2.5 |
| Shelter cost per person (USD) | $2 | $50 | >$147 | $74 | $73 | $64 | $31 | $72 | $46-117 | $107 | $584 | $895 |
| Construction time (hrs) | unknown | 2 | 3 | 4 | 4 | 4 | 4 | 48 | 6 | 48 | 96 | 48 |
| Construction team (# people) | unknown | 2 | 2 | 3 | 3 | 3 | 3 | 4 | unknown | 5 | unknown | unknown |
| 2 year shelter use cost (USD) | $66 | $400 | $750 | $600 | $375 | $330 | $190 | $500 | $700 | $625 | $3,100 | $4,600 |
| 2 year cost per person (USD) | $11 | $100 | $219 | $131 | $73 | $64 | $37 | $97 | $163 | $122 | $603 | $894 |
| 4 year shelter use cost (USD) | $132 | $800 | $1,500 | $1,200 | $375 | $430 | $220 | $1,000 | $1,050 | $775 | $3,300 | $4,700 |
| 4 year cost per person (USD) | $23 | $200 | $438 | $263 | $73 | $84 | $43 | $194 | $245 | $151 | $642 | $914 |
| Total shelters used after 4 years[5] | 12 | 4 | 3 | 4 | 1 | 2 | 4 | 4 | 3 | 4 | 3 | 2 |
| Material type | 60 gsm polyethyl. | 300 gsm poly duck | 420 gsm canvas | 300 gsm poly duck | 800 gsm PVC poly | 300 gsm poly duck | 60 gsm polyethyl. | bamboo, eucalyptus | OSB, dim. Lum. | timber, palm matt | timber, tarp, iron | galv steel, tarp |
| Reusable frame (x-yes,o-maybe) | | **o** | **X** | **o** | **X** | **X** | **X** | **o** | | **o** | **o** | **X** |
| Reusable skin (x-yes,o-maybe) | | | **o** | | **X** | **o** | | | **o** | | | |

1 based on 3.5m²/person Sphere Standards
2 shelter durability results from Joseph Ashmore's independent assessment of Haitian relief shelters and IFRC Transitional Shelters Eight Designs assessment booklet
3 weight of the steel frame imported from Spain
4 LWET – Light Weight Emergency Tent
5 If shelters are replaced at time specified

**Fig. 5.05**

Fig. 5.05 (above)
Comparing shelter cost, weight, and durability for tents, BWSTR series, and transitional shelters

In Fig. 5.05 is a comparison between humanitarian supplied relief tents, thesis design proposals, and humanitarian supplied transitional shelters. Material weight, structure durability, and cost are factors that should be considered when determining if there is a need for transitional shelters.

## New vs Reuse
(cost comparison)

The 'New vs. Reuse' chart (Fig. 5.06) presents a factual disaster event(s) comparing the reuse of BWSTR Series shelters and humanitarian supplied tents. Humanitarian aid tents have a lifespan of one year, and must be replaced annually if they are to maintain the "adequate shelter" status. The country used for cost comparison analysis will be Pakistan during the rainy season. It will show the need for shelter in times of monsoon rain for the years of 2010, 2011, and 2012.

| | | # | **Pakistan July 2010**: *Monsoon rains lead to extensive Indus River flooding (actual: ridge tent supplied)* A | **Pakistan July 2011**: *Monsoon rains cause flooding Ghanche District in Gilgit-Baltistan (actual: ridge tent supplied)* B | **Pakistan August 2012**: *Monsoon rains flood in parts of Punjab, Sindh, Balochistan (actual: ridge tent supplied)* C |
|---|---|---|---|---|---|
| Population affected | Actual | 1 | 20,000,000 | 6,000,000 | 4,400,000 |
| Homes destroyed | Actual | 2 | 1,790,000 | unknown | 465,424 |
| IDP Population | Actual | 3 | 6,300,000 | 1,800,000 | 742,209 |
| Tents required | Actual | 4 | 2,200,000 | 300,000 | 150,000 |
| Tents supplied | Actual | 5 | 1,000,000 | 112,000 | 100,000 |
| Tent cost | Actual | 6 | $200 | $200 | $200 |
| Tent type supplied | Actual | 7 | Dbl Fly Ridge Tent | Dbl Fly Ridge Tent | Dbl Fly Ridge Tent |
| Total tent cost (approx.) | Actual | 8 | $200,000,000 | $22,400,000 | $20,000,000 |
| Thesis shelter recommended | BWSTR | 9 | BWSTR 02s | BWSTR 02s | BWSTR 02s |
| Recommended shelter cost | BWSTR | 10 | $350 | $350 | $350 |
| Total suggested tent cost | BWSTR | 11 | $350,000,000 | $39,200,000 | $35,000,000 |
| Shelter repair cost BWSTR1 | Scenario 1 | 12 | n/a | $1,323,810 | $1,482,430 |
| Shelter cost per person (supplied)[2] | Scenario 1 | 13 | $50 | $50 | $50 |
| Shelter cost per person (thesis)[2] | Scenario 1 | 14 | $70 | $70 | $70 |
| Shelter cost per person (reuse) | Scenario 1 | 15 | n/a | $12 | $15 |
| yearly total cost per person (supplied) | Scenario 1 | 16 | n/a | $100 | $150 |
| yearly total cost per person (reuse) | Scenario 1 | 17 | n/a | $82 | $97 |
| | Scenario 1 | | Dbl Fly Ridge Tent | 3 year total | $242,400,000 |
| | Scenario 1 | | BWSTR 02s | 3 year total | $352,806,240 |

Reuse savings
1) 15% skin needing repair, 2% need frame replacement
2) based on 3.5m²/person Sphere Standards*
* most tents in Pakistan held more people than suggested in sphere standards

| | | | | | |
|---|---|---|---|---|---|
| Tents supplied | Scenario 2 | 18 | 1,000,000 | 412,000 | 250,000 |
| Shelter repair cost BWSTR[1] | Scenario 2 | 19 | n/a | $2,443,045 | $1,526,903 |
| Shelter cost per person (supplied)[2] | Scenario 2 | 20 | $50 | $50 | $50 |
| Shelter cost per person (thesis)[2] | Scenario 2 | 21 | $70 | $70 | $70 |
| Shelter cost per person (reuse) | Scenario 2 | 22 | n/a | $5.93 | $6.11 |
| yearly total cost per person (supplied) | Scenario 2 | 23 | $50 | $100 | $150 |
| yearly total cost per person (reuse) | Scenario 2 | 24 | n/a | $76 | $82 |
| | Scenario 2 | | Dbl Fly Ridge Tent | 3 year total | $332,400,000 |
| | Scenario 2 | | BWSTR 02s | 3 year total | $353,969,948 |

Section Summary:
The Roman arch was chosen as the final shelter design shape, because of its airflow properties (specifically ventilation qualities). In the prolonged bend test, the fibreglass rod performed better than expected. BWSTR Series shelters range in price from $47-500 dollars and weigh between 51-138 kgs. Most of the variation in cost and weight is due to the differences between skin fabric types. The higher quality BWSTR shelters may last well over 4years, due to the wear resistance capacities of synthetic polymer materials. The BWSTR shelter system may actually cost less over time if the shelter is repaired (if needed), stored properly, and then reused.

In next section:
The final chapter summarizes the main points introduced in this thesis. Design choices will be explained in greater detail. There will be suggestions made to allow the continuation of this research.

| | | D | E | F |
|---|---|---|---|---|
| | | ***Pakistan July 2010**: Monsoon rains lead to extensive Indus River flooding (simulation: LWET 4.1 supplied)* | ***Pakistan July 2011**: Monsoon rains cause flooding Ghanche District in Gilgit-Balistan (simulation: LWET 4.1 supplied)* | ***Pakistan August 2012**: Monsoon rains flood in parts of Punjab, Sindh, Balochistan (simulation: LWET 4.1 supplied)* |
| 1 | LWET 4.1 | 20,000,000 | 6,000,000 | 4,400,000 |
| 2 | | 1,790,000 | unknown | 465,424 |
| 3 | | 6,300,000 | 1,800,000 | 742,209 |
| 4 | | 2,200,000 | 300,000 | 150,000 |
| 5 | | 1,000,000 | 112,000 | 100,000 |
| 6 | | $300 | $300 | $300 |
| 7 | | LWET Version 4.1 | LWET Version 4.1 | LWET Version 4.1 |
| 8 | | $300,000,000 | $33,600,000 | $30,000,000 |
| 9 | BWSTR | BWSTR 02s | BWSTR 02s | BWSTR 02s |
| 10 | | $350 | $350 | $350 |
| 11 | | $350,000,000 | $39,200,000 | $35,000,000 |
| 12 | Scenario 3 | n/a | $1,323,810 | $1,482,430 |
| 13 | | $50 | $50 | $50 |
| 14 | | $70 | $70 | $70 |
| 15 | | n/a | $12 | $15 |
| 16 | | n/a | $100 | $150 |
| 17 | | n/a | $82 | $97 |
| | | LWET Version 4.1 | 3 year total | $363,600,000 |
| | | BWSTR 02s | 3 year total | $352,806,240 |
| 18 | Scenario 4 | 1,000,000 | 412,000 | 250,000 |
| 19 | | n/a | $2,443,045 | $1,526,903 |
| 20 | | $50 | $50 | $50 |
| 21 | | $70 | $70 | $70 |
| 22 | | n/a | $5.93 | $6.11 |
| 23 | | $50 | $100 | $150 |
| 24 | | n/a | $76 | $82 |
| | | LWET Version 4.1 | 3 year total | $432,400,000 |
| | | BWSTR 02s | 3 year total | $353,969,948 |

**Fig. 5.06**

Fig. 5.06 (both pages)
The numeric values in rows 1 - 8 of columns A, B, C, are factual representations of the number of people affected, displaced population, total homes destroyed, tents required, and tents distributed during the monsoon flooding of 2010, 2011, and 2012 in Pakistan. Rows 1-8 will be referred to as: Actual.

Figures in rows 9 – 11 of columns A – F show the cost of using thesis design BWSTR 02s instead of the dbl fly ridge tent. It is represented as: BWSTR on the chart.

In rows 1 – 8 of column D, E, F, a hypothetical response is depicted where th humanitarian response uses their newly developed LWET 4.1 in stead of dbl fly ridge tent. This section of the chart is labelled LWET 4.1.

Scenario 1 (rows 12 – 17 of A,B,C), compares the difference in cost per person between reusing disaster relief tents (BWSTR 02s) and buying a new dbl fly ridge tent each year. There will be a replacement cost associated with reusing BWSTR Series tents. For the purposes of this chart, 15% skin repairs and 2% frame replacement will be used as the cost associated with reuse.

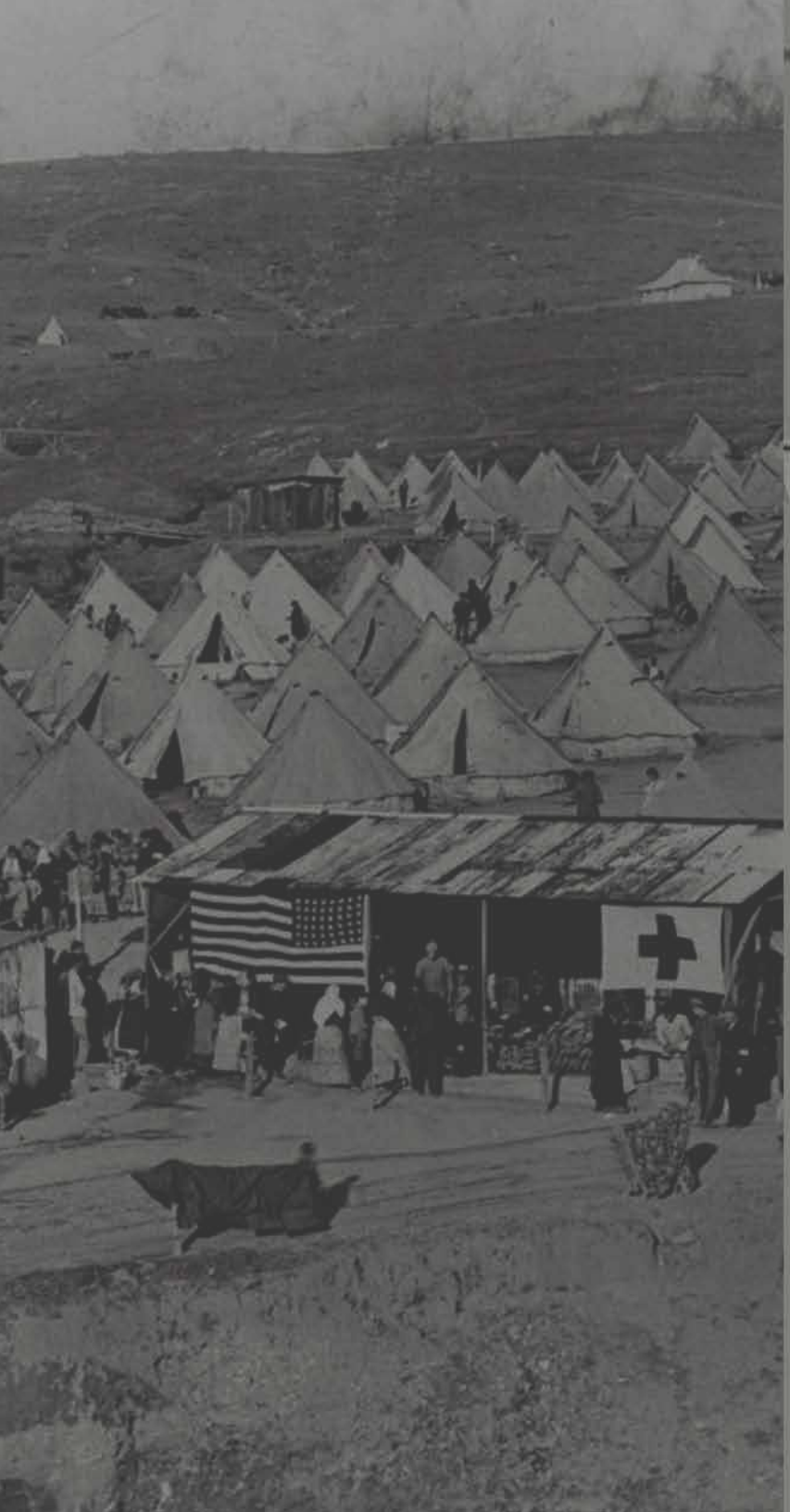
Scenario 2 (rows 18 – 24 of A,B,C), is very similar to scenario 1, except that in scenario 2 during the years of 2011 and 2012 the total number of shelters used is the number of shelters provided plus the number of shelters required.

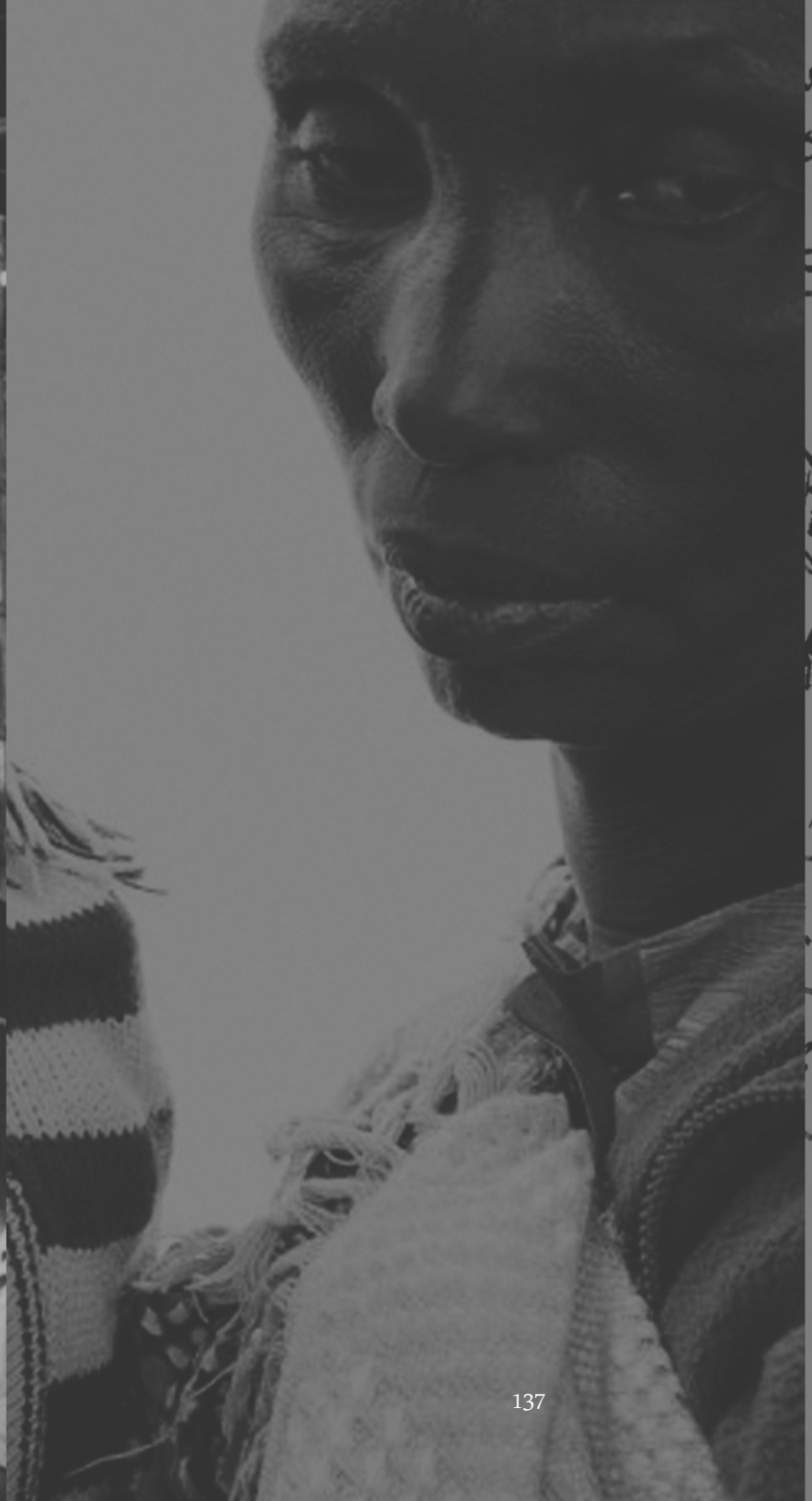
Scenario 3 (rows 12 – 17 of D,E,F), is similar to scenario 1, but in scenario 3 the LWET 4.1 is supplied by humanitarian organizations instead of the dbl fly ridge tent. The reuse of BWSTR 02s is compared to purchasing new LWET 4.1 each year.

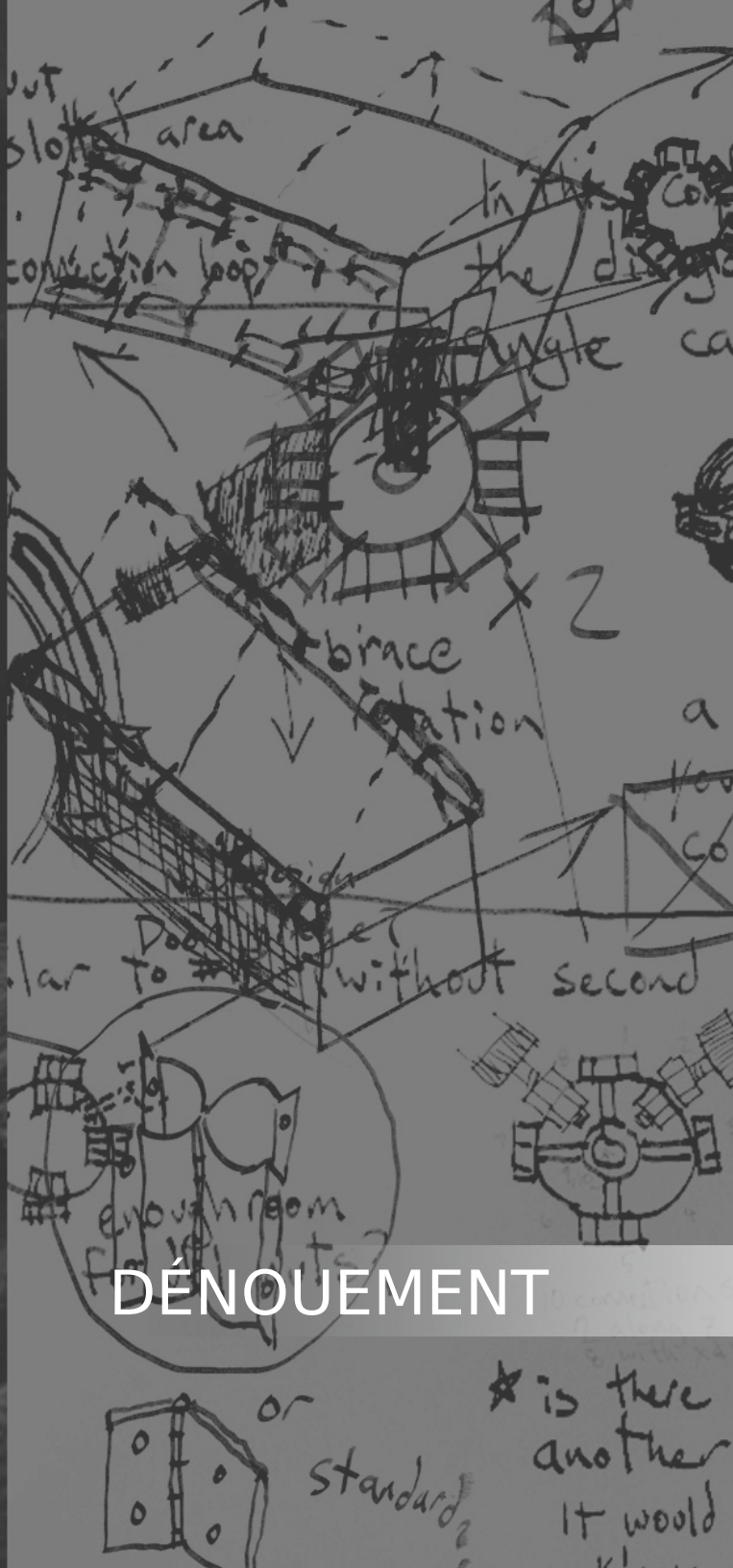
Scenario 4 (rows 18 – 24 of D,E,F), uses the exact same comparison method as scenario 2, only LWET 4.1 is supplied by humanitarian organizations instead of the dbl fly ridge tent.

In scenario 1 the BWSTR option is 45.5% more than the Dbl Fly Ridge Tent option.
In scenario 2 the BWSTR option is 6.5% more than the Dbl Fly Ridge Tent option.
In scenario 3 the LWET 4.1 option is 3.1% more than the BWSTR option.
In scenario 4 the LWET 4.1 option is 22.2% more than the BWSTR option.

1. Kleiser, G, "Dictionary of Proverbs." APH Publishing, New Dehli. 2005. http://books.google.ca/books?id=OIAUDXRQ4ilC&printsec=frontcover&dq=dictionary+of+proverbs&hl=en&sa=X&ei=neKqUMC7Habw2QXd94GYDg&ved=0CDQQ6wEwAQ



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# DÉNOUEMENT


F01

# Thesis Compendium

Image F01 (opposite)
The conditions in Myanmar six months after Cyclone Nargis. Cyclones with the strength of Nargis will increase in frequency of occurence.

Throughout the first four chapters of this thesis, various aspects were presented of how humanitarian organizations respond during a disaster response. There will be a short recap of these points before continuing to the thesis conclusions.

Current environmental analysis shows that natural disasters will increase with intensity and frequency in the future. Although natural disasters occur in both developed and developing nations, it affects developing nations the most. The humanitarian industry responds to natural disaster within in hours of the tragic event. The first shelters to arrive at a disaster zone are tents and sheets of plastic, more commonly known as 'tarps'. The tent has been a tested and proven emergency shelter method for over 1,000 years, if not longer. The tarp as an emergency shelter is something that has been introduced within the last decade. The tarp is not a preferred emergency shelter from the perspective of beneficiaries who receive it. Unfortunately, both emergency shelters do not last beyond the time span of one year, and the tarp fails much sooner at about the three-month range. Attempts have been made to adopt regional tent typologies like the yurt or black tent as a disaster response, however, these tents were often too heavy and the materials needed are in short supply. Even with the large budgets of humanitarian organizations after a disaster, they can still only effectively target 20% of the affected population. The other 80% must salvage whatever materials are available to construct their own shelter. Sometimes, this can have a disastrous effect on the surrounding environment if materials to construct shelters are taken from fragile ecosystems.

After the initial emergency response, typically, humanitarian organizations will offer beneficiaries a transitional shelter (if it is within the scope of

(see page 158 for end notes)

budget). Transitional shelter is called the second phase of relief after a disaster, it is also tied closely to the reconstruction and development phase of the response (phase three). Transitional shelters are offered as temporary living conditions for a duration of less than five years, unless the transitional shelter itself can be upgraded into a permanent dwelling. The reconstruction process after a disaster could be as short as six months, or in some instances last longer than five years. For those that did not receive a transitional shelter, it is not uncommon to find people displaced by a natural disaster still living in a tent even five years after the event occurred.

All too often people that have lost their homes from a natural disaster, who were also fortunate enough to receive an emergency shelter from an aid organization will inhabit that emergency shelter throughout the reconstruction process. This reconstruction process generally lasts over two years in time. There are certain funding complications arising from the donation process that can extend the time it takes for reconstruction considerably. The time period between the initial emergency response and the permanent reconstruction phases when finacial resources have been exhausted is called the 'funding gap'. This funding gap is a typically a reoccurring event for each disaster response, and stems from poor monetary planning. Since people will still be living in their emergency shelters during this time period, emergency shelters should be made from more robust materials that can handle lengthy habitations.

In order for emergency relief shelters like tents to be inhabited for long durations, skin materials made from engineered synthetic polymers should be used. PVC-coated polyesters, silicone coated fibreglass, and Teflon fabrics each provide a viable solution, as well as, having inherent puncture resistance qualities. Puncture resistance will greatly improve the security features of a durable emergency tent. Vulnerable populations such as: the elderly, the disabled, and children, would benefit from using durable and secure emergency shelters. More robust shelters will be less likely to need repair during the habitation time period.

Emergency shelters should meet certain criteria in order to be considered as a post-disaster shelter. According to Sphere Standards, they should be at least 18m². This amount of space is enough to accommodate five people. They should also be light-weight and packaged in a manner that increases shipment efficiency. It is important to be able to pack as many shelters as possible into a 6m shipping container. This will help decrease shipment cost and maximize how many shelters can be transported to the affected area.

Fibreglass was tested as a potential framing material for BWSTR Series shelters as well. (After a fibreglass rod was bent at almost 90° during a period of 60 days, the rod later showed very little deformation. Fibreglass pipe was selected as the framing material as the result of that test.) Fibreglass is almost as strong as steel, but is much lighter in weight.

Unfortunately, the current options available to humanitarian organizations regarding emergency shelters are far from 'perfect'. None of the tents given by donors will last longer than a year. This thesis proposes a durable emergency shelter in the shape of a barrel tent, using high-strength synthetic materials. The Roman arch/barrel shape was chosen because of its superior wind flow properties. These wind flow properties allowed ventilation air to flow throughout the shelter, which will increase the comfort level in warm climates. The barrel shape is strong, holds against wind loads well and sheds water effectively.

## Summation of Design Priorities

During the design process and research analysis, it was decided that several factors must be addressed for an emergency shelter beyond mere environment protection. These factors included security, material durability, shelter repair, ability to be reused, ease of assembly, and climatic/ cultural customization. If these criteria are met, especially within the realm of durability, security,

shelter repair, the BWSTR Series shelter will have the capacity to replace or remove the transitional shelter phase.

SECURITY characteristics of the BWSTR Series emergency relief shelter are addressed by using high-performance synthetic fabrics. Fabrics like 1000 denier 800g/sqm PVC-coated polyester (Image F02) are commonly used in the fabrication of inflatable boats. This fabric offers a puncture resistance well above that of ripstop nylon fabrics that are supplied with conventional retail tents. Materials which are not resistant to punctures or slices from sharp objects, should be coupled with a second skin that acts as a security layer inside the shelter. This security skin can be manufactured with materials such as: braided nylon rope, polypropylene fish nets, or galvanized chicken wire.

Other security measures incorporated within the BWSTR shelter design are the opening fastener choice. Door, window, and ventilation openings are closed using strap fastening system and can be strapped shut from both the inside, as well as the outside.

LIMITATIONS with security come from the cost and weight of the fortified skin solutions. Additional weight can drive up the cost of shipping, tire the people transporting/loading the shelters, and add extra weight loads to the shelter frame. The increased cost of these skins will only allow for a certain number of people to receive a durable shelter solution, while other people are left with nothing. Cost efficient shelters will lead to more shelters being supplied to beneficiaries. Secure skins have a higher cost. By selecting a less safe, lower weight, and less-expensive shelter skin you have to add an additional skin layer for security in order to match the security of more protective skins. When you add a second skin for security such as netting or chicken wire, this too also increases weight and cost.

DURABILITY is intrinsically connected to which materials are selected to manufacture a BWSTR Series shelter. Increased durability will allow for BWSTR Series emergency shelters to be inhabited beyond the emergency phase of the disaster relief effort. BWSTR series shelters manufactured with quality skin and frame materials will be durable enough dwellings to house people all the way until the end of the reconstruction period. Skins that have great durability ratings also have high security ratings.

PVC-coated polyester and properly treated heavy-duty cotton/polyester canvas are more durable than ripstop nylon (commonly supplied with retail tents) and polyethylene sheeting (emergency relief tarps). Nylon strapping was sewn around the openings, seams, and perimeter, to increase the durability of the skin. This strapping will act as a strength border and mitigate against any seam wears or tears that start at skin openings.


F02

The frame is another component of the shelter that requires careful consideration. Steel, wood, bamboo, carbon fibre, and fibreglass are all durable frame options. However, some are more impervious than others. Steel is plagued with heavy weight and oxidization characteristics, which eliminates it as a BWSTR Series shelter frame material. Wood and bamboo both are somewhat light-weight and have admirable strength thresholds, but unfortunately, both are prone to attack from insects, moisture, and moulds. This leaves carbon fibre and fibreglass as potential frame materials. Both are light-weight and have high-strength characteristics. Fibreglass was chosen over carbon fibre because it was one-tenth the

Image F02 (above)
Highlighting the cutting resistance inherent of 800gsm 1000D*1000D PVC coated polyester fabric material.

price and performs almost as well as carbon fibre.

LIMITATIONS stemming from issues surrounding durability, revolve around cost and weight. Additionally, the inappropriate selection of a skin materials for the climate at the shelter destination. Cotton canvas is not a good skin choice for regions with extended rainy seasons. Plastics do not fare well in hot climates. Polyethylene sheeting deteriorates very quickly in hot sunny climates from prolonged UV exposure. PVC-coated polyester skins that are durable and secure do not breathe well. Using these materials without proper ventilation could lead to an unbearably hot shelter interior.

SHELTER REPAIR solutions or methods should be considered before making material selections. By utilizing skins and frames that can be repaired, the shelter may become more environmentally friendly. Shelter lifespan can increase significantly if skins are replaced or repaired when they show signs of wear. Humanitarian agencies can maintain a constant level of acceptable shelter conditions in situations when permanent reconstruction takes longer than expected.

Cotton canvas and ripstop nylon can be sewn if torn, while PVC-coated polyester is more difficult to sew. This can still be accomplished as well. It is better to use PVC glue to attach another strip of PVC-coated polyester over a hole in a skin made of PVC-coated polyester. Polyethylene sheeting does not repair well. Once this material begins to fray, it loses the ability to remain waterproof. Repairs with stitching will not stop the fraying process. Fibreglass frames can be repaired using resin and glass cloth. These items are readily available worldwide. Poles can also be repaired by winding rope around the break/splinter.

LIMITATIONS will again be linked to costing issues. Items/materials that can be repaired will cost more than a one-time use (throw away) shelter skin or shelter frame.

REUSE is an important design component of BWSTR Series emergency shelters. The reuse of emergency shelters will help the environment by eliminating excess waste created by one-time use shelters. Jobs may be created during the process of cleaning, sanitizing, and repairing BWSTR shelters. When skins deteriorate beyond repair, skins can be replaced then attached to the durable fibreglass frame (which can be reused many times).

LIMITATIONS from reuse will be attributed to material cost as well as storage cost. Where will these shelters be stored after they have been used? If there is a storage facility, who will ensure they are stored properly to ensure that the shelters will not be damaged from mold and mildew.

ASSEMBLY of BWSTR shelters must remain simple. The entire shelter can be put together using only a pair of pliers (or similar tool like: adjustable wrench, plumbing wrench, etc...). The ropes, eyelet bolts, washers, and wingnuts supplied with BWSTR shelters can be replaced anywhere in the world.

LIMITATIONS due to ease of assembly, relate to increased shipment volumes from removing non-essential connectors. Fibreglass piping may have been condensed if it was assembled with multiple connectors.

CUSTOMIZATION of BWSTR shelters, both climatically and culturally, can be done through the material and colour selection process.

The selection of the skin material will address environmental issues (canvas is a better choice for hot dry climates, etc...). Polyethylene and ripstop nylon skin options are more economical. However, they do not possess the durability qualities that are inherent to more robust shelter skins (PVC-coated polyester and heavy-duty cotton/polyester canvas).

Colours can be chosen for the nylon strapping and the shelter skin. Choosing a colour that represents the region's national colours may help garner a sense of pride throughout the recovery process.

LIMITATIONS with colour are due to political relations. In some conflict-prone areas of the world, colour represents where your allegiance lies. People given the wrong colour shelter may do worse to the donor organization than simply not inhabit the emergency shelter.

BWSTR Series shelters are only customizable with regards to material selection. At the moment, there are no upgrades that can be integrated with the BWSTR shelter, which makes them inflexible. BWSTR shelters are a single solution design, this means the design can be implemented anywhere within Tropic of Cancer at latitude 40°N and

below the Tropic of Capricorn at latitude 40°S. Single-solution designs do not perform the same within different regions of the globe.

GROUND CONNECTION has been done using ground screws and spiral guy rope anchors for most of the models within the BWSTR Series shelters.

LIMITATIONS with the currently selected anchors and ground screws have to do with heavy weight characteristics associated with steel. Ground screws and spiral anchors do not perform well in hard/rocky soils. Other options must be investigated to include multiple types of soil anchorage. Ground screw placement is also too precise. An anchorage system needs to be employed that has a little bit more flexibility.

Stilts for the shelter to rest on in flood-prone areas were not included with BWSTR shelters. They were not included due to the heavy weight of an incorporated stilt system. Safety measures should be considered if the emergency shelter must be assembled on or near a flood plain. The recommendation is to construct a raised platform using timber or bamboo (using found material or from other sustainable sources). Raised earth platforms may not hold well against sustained flooding. Shelters constructed on stilt platforms will need to have a connecting accessory supplied with the shelter so it can be attached to the platform.

BWSTR WEIGHT ranges from 47-137 kgs, depending on which materials are selected from Fig 5.02. Again, material selections should be carefully considered taking into account what is appropriate for the climate of the region, the security needs of the beneficiaries, and the budget of the donor organization.

LIMITATIONS are once more associated with weight. Durable shelter solutions most often have heavier weight values.

EXTERNAL LIVING areas are incorporated into the design of the BWSTR Series shelters. There is a 3 m² outdoor living area on both the front and back of the thesis-designed emergency shelter. This living area was not included in the total living space of the BWSTR shelter. It offers a place to sit in the shade during hot times of the day.

LIMITATIONS with the awning will be due to its shape. Unfortunately, this awning would be damaged in high winds from a severe storm. If the awning is not rolled up before a storm and secured to the ground using timber stakes, there is the potential to severely damage the rest of the shelter (tearing away from shelter, snapping guy ropes, detaching shelter from ground anchors, etc...).

STORM SURVIVAL capabilities of BWSTR Series shelters was an influential part of the design process. Ensuring that the shelter would not be penetrated excessively by driving rains and the shelter would not be lifted from the ground in high wind scenarios. Choosing spiral anchors for the guy ropes will help keep the shelter from lifting from the ground. The roof overlap that joins the top and bottom skins was extended in order to minimize the amount of rain that could be penetrated between the top and bottom skins. Straps that close doors were added on both the exterior and interior of the shelter. This will help to prevent window and door materials from being blown open in high wind situations. As demonstrated on page 97, materials specified for use within the BWSTR Series shelters can all withstand at least tropical storm force winds.

LIMITATIONS surrounding the storm surviving characteristics of BWSTR Series shelters are centered around the unpredictability of severe storms. Materials may theoretically handle high winds within mathematical calculations, however, nature does not act always as predicted. Beneficiaries should not stay inside BWSTR Series shelters during severe storms and should seek proper shelter. Tidal surges can lead to flooding and high winds will lead to flying debris. Essentially, no matter how strong BWSTR shelters are designed (with the intentions to withstand high winds) the more than likely outcome would be their destruction.

BWSTR Series emergency shelters have been designed to accommodate the needs of humanitarian industry now. They have the capabilities to be used as a durable emergency shelter and can replace the transitional shelter phase. Limitations presented here must be addressed before the shelter can be used in the field.

# Tent Comparison Summary

The graphs shown on the next pages use information from Fig. 5.04 and Fig. 5.05 on pages 130-131 from the *Development* section of the thesis. These graphs show BWSTR 01s has the potential to be the superior shelter of the comparison group.

These have been displayed in order from poor performing shelters to better possible options. A 5 on the rose diagram denotes that the shelters performs well in specified area, or that it is a important feature in its design. Emphasis was placed on frame and skin durability. Also, security was another factor of importance.

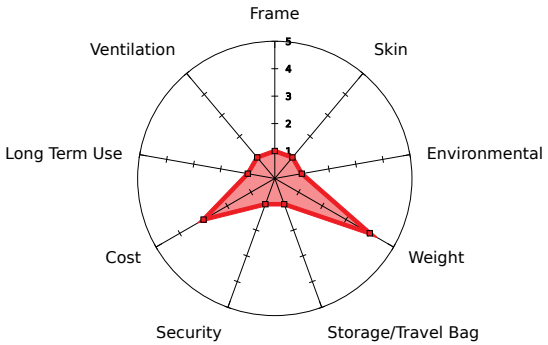
Images F03 - F10 (following pages)
The rating order of the tents compared from poor to best.

Fig. 6.01 - 6.08 (following pages)
Shelters were compared against one another by the following criteria: ventilation, frame strength, skin durability, environmental impact, weight, integrated travel bag/container, security performance, overall cost, and long term use performance.

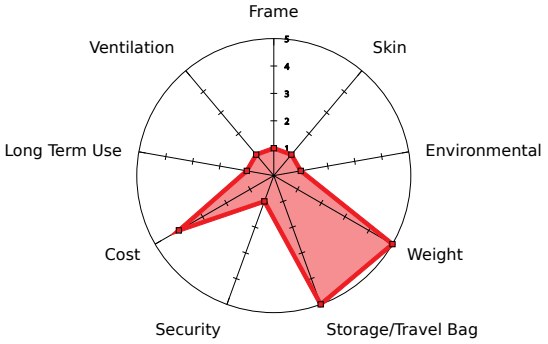
Rose Diagram Grading Criteria:
ventilation - 5 = great airflow into shelter
frame strength - 5 = high breaking strength
skin durability - 5 = puncture, UV, and water protection
environmental impact - 5 = reuse, recyclable, or low environmental impact
weight of shelter - 5 = low weight
integrated travel bag/container - 5 = container/bag provided for storage/shipping
security - 5 = high puncture and slice resistance
cost - 5 = low cost
long term use - 5 = long extension(s) of time as adequate shelter

F03

F04




Dome Tent **Fig. 6.01**




Retail Tent **Fig. 6.02**

Shelter Material Qualities:
- ripstop nylon skin
- small diameter fibreglass rod frame
- zipper used as opening fastener

Security Qualities:
- skin material easily cut open
- zipper easily opened

Positive Point:
- aerodynamic shape

Shelter Material Qualities:
- ripstop nylon skin
- small diameter fibreglass rod frame
- zipper used as opening fastener

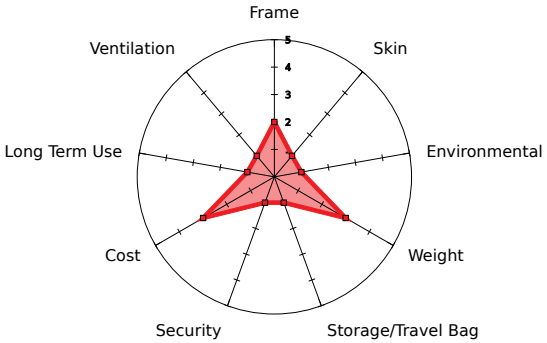
Security Qualities:
- skin material easily cut open
- zipper easily opened

Positive Point:
- lightweight
- supplied with storage bag

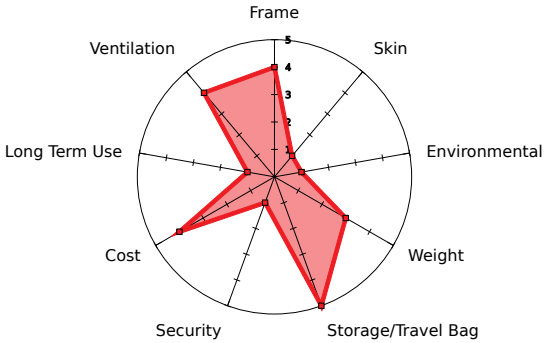
F05

F06

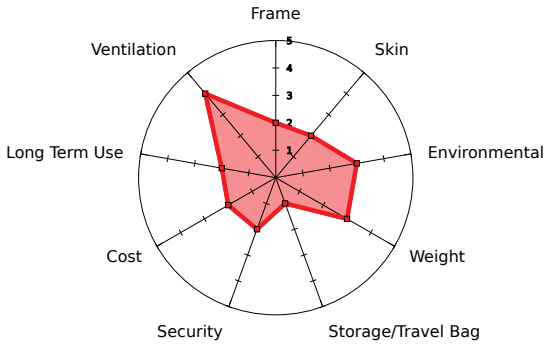
F07




Barrel Tent **Fig. 6.03**




BWSTR 08p Tent **Fig. 6.04**




Dbl Fly Ridge Tent **Fig. 6.05**

Shelter Material Qualities:
- ripstop nylon skin
- small diameter fibreglass rod frame
- zipper used as opening fastener

Security Qualities:
- skin material easily cut open
- zipper easily opened

Positive Point:
- aerodynamic shape

Shelter Material Qualities:
- polyethylene skin
- medium diameter fibreglass pipe frame
- rope ties used as opening fastener

Security Qualities:
- skin material easily cut open
- rope ties easily opened

Positive Point:
- strong frame
- aerodynamic shape and good ventilation qualities

Shelter Material Qualities:
- 100% cotton canvas skin
- medium diameter steel pipe frame
- rope ties used as opening fastener

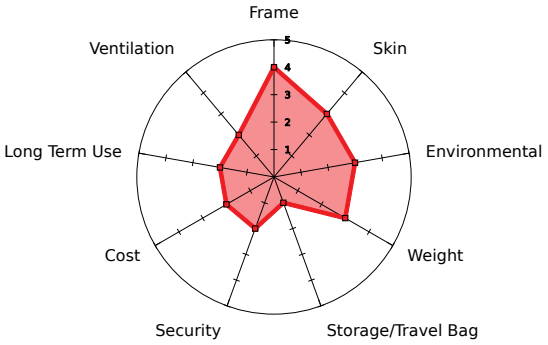
Security Qualities:
- skin material can still be cut open
- rope ties easily opened

Positive Point:
- dbl fly buffers air temperature around tent
- cotton performs well in warm climates

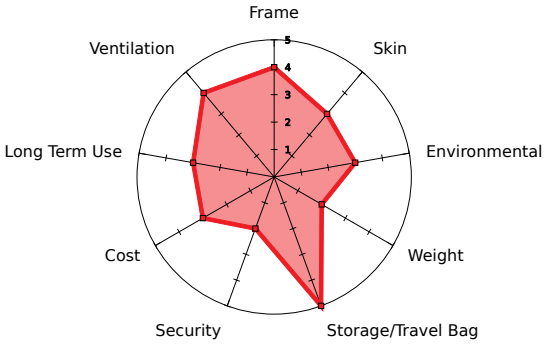

F08


F09

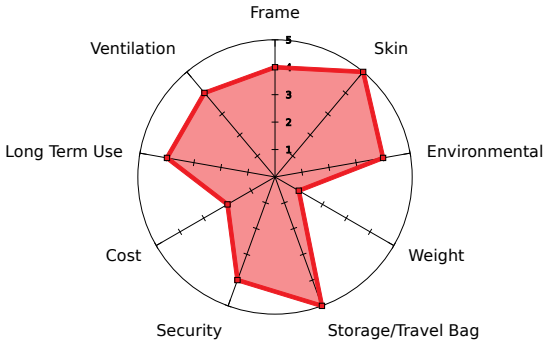

F10




LWET 4.1 Tent **Fig. 6.06**




BWSTR 05c Tent **Fig. 6.07**




BWSTR 01s Tent **Fig. 6.08**

Shelter Material Qualities:
- cotton/polyester blend canvas skin
- medium diameter lightweight metal frame
- rope ties used as opening fastener

Security Qualities:
- skin material can still be cut open
- rope ties easily opened

Positive Point:
- cotton/polyester blends perform very well in warm climates

Shelter Material Qualities:
- cotton/polyester blend canvas skin
- medium diameter fibreglass pipe frame
- straps used as opening fastener

Security Qualities:
- skin material can still be cut open
- straps can be fastened on both the inside and outside

Positive Point:
- strong frame
- supplied with storage container
- aerodynamic shape and good ventilation qualities

Shelter Material Qualities:
- PVC coated polyester skin
- medium diameter fibreglass pipe frame
- straps used as opening fastener

Security Qualities:
- skin material difficult to cut open
- straps can be fastened on both the inside and outside

Positive Point:
- strong frame, strong skin
- supplied with storage container
- aerodynamic shape and good ventilation qualities

# Global Locations and BWSTR Model Selection

Due to the complexities of design and issues surrounding weight, it was decided from the beginning that this shelter will only operate in warm climates. Specifically, regions around the globe that do not dip below 6°C. The BWSTR Series emergency shelters have many seams designed specifically to enhance ventilation and wind flow through the shelter. These seams have poor insulating capabilities and would allow excessive amounts of heat to escape if used in cold climates. There is much potential for the ridge tent shape that was tested in the wind simulator to be used in colder climates.

Several locations across our globe were selected as hypothetical testing grounds for the BWSTR shelters. These locations were selected due to their broad range in temperature conditions, as well as their differences in weather patterns and their medium to high risk of reoccurring natural disasters. Which BWSTR models will be selected is based on the skin materials that will perform best in the climates of the chosen locations.

Colour is another factor that must be considered for the final shelter design. White is the colour that performs best against UV degradation. Although white may have inherent UV protection properties, it is also prone to showing accumulations of dust and debris deposits. Dark colours will perform poorly in warm climates. They are commonly attributed with massive amounts of heat gain from the sun's rays. Not only does colour have influence the comfort level of the shelter, it may have social impacts as well. Some colours are a source of pride for a culture if the colour is associated with their country or national flag. Colours may also spark tension as they are inherently political by nature. Colours will be used to invoke a sense of national pride through the recovery process must be selected carefully, as not to offend other cultures.

1. Puerto Cabezas, Nicaragua
January low/high temp - 23C/27C
July low/high temp - 26C/28C
Annual precipatation - 2970 mm
Avg windspeed - 16 km/h (22 km/h in July)
UV index (July) – 10-13 +
Suggested colour – light yellow, light orange, light blue, light green, tan, white
Advised material - ripstop nylon, PVC-coated polyester
Proposed shelter type - BWSTR 02s

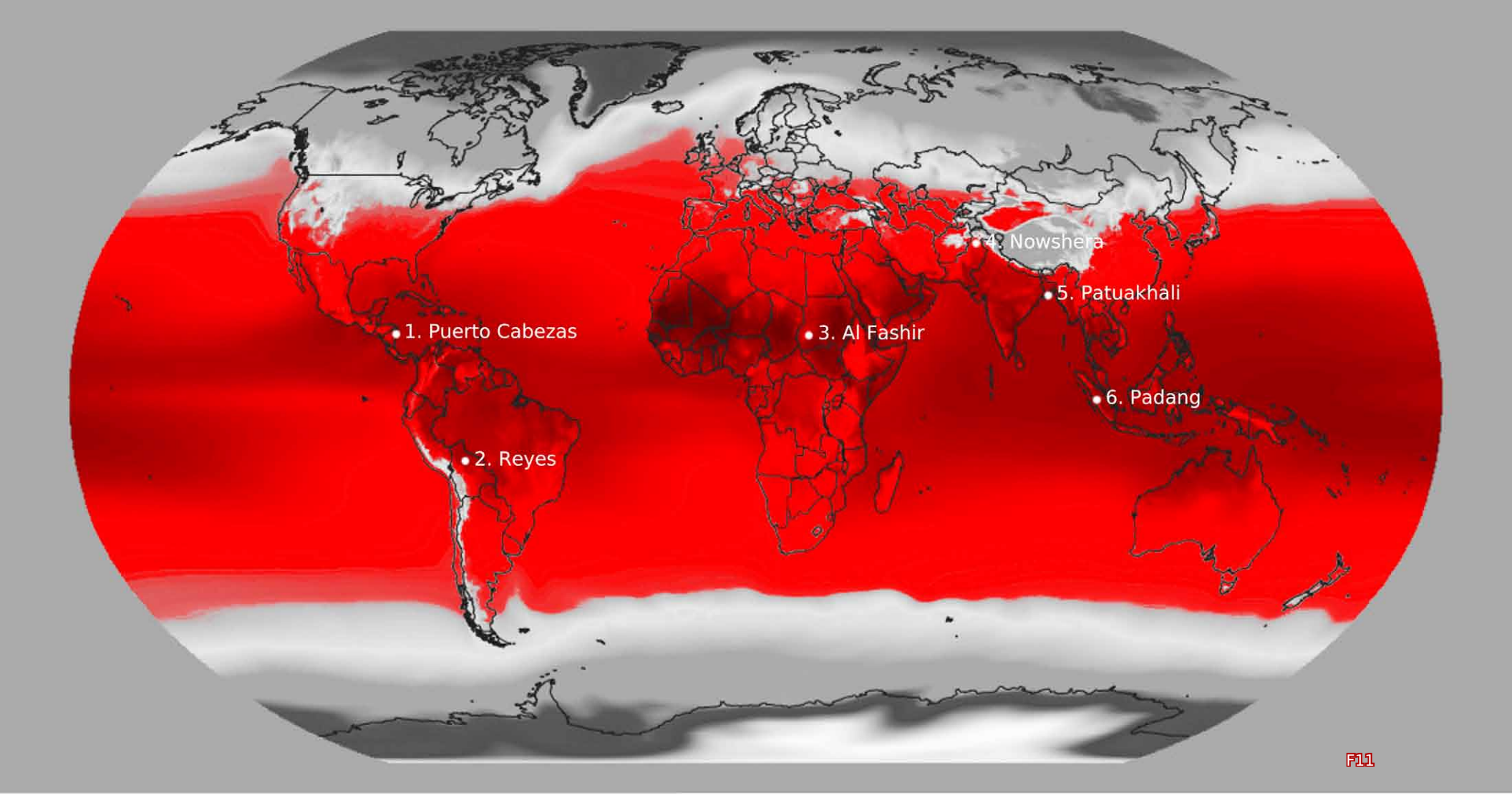
2. Reyes, Beni, Bolivia
July low/high temp - 14C/27C
September low/high temp - 20C/35C
Annual precipatation - 1972 mm
Avg windspeed - 15 km/h
UV index (October) – 14 +
Suggested colour - light yellow, light red, light green, tan, white
Advised material - ripstop nylon, PVC-coated polyester
Proposed shelter type - BWSTR 06n, BWSTR 07n

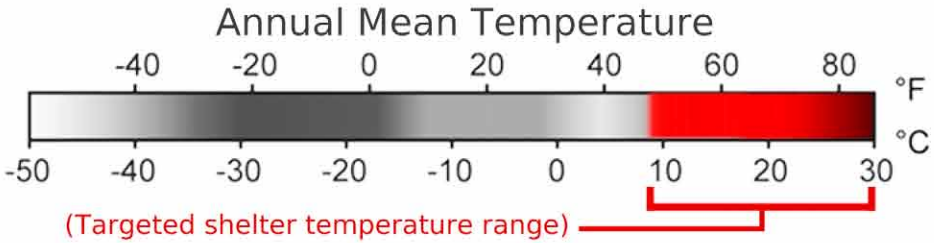
3. Al Fashir, Darfur, Sudan
December low/high temp - 9C/30C
May low/high temp - 21C/38C
Annual precipatation - 259 mm
Avg windspeed - 3 km/h
UV index (July) – 11-13 +
Suggested colour – tan, light brown, white, light green, light red
Advised material – cotton canvas, polyester/cotton canvas
Proposed shelter type - BWSTR 03c, BWSTR 04c, BWSTR 05c

4. Nowshera, Khyber Pakhtunkhwa, Pakistan
January low/high temp - 4C/16C
June low/high temp - 27C/38C
Annual precipatation - 350 mm
Avg windspeed - 6 km/h
Sun intensity (UV index) – 11-13 +
Suggested colour – tan, light brown, light green, green, white
Advised material – polyethylene, ripstop nylon, cotton/polyester canvas
Proposed shelter type - BWSTR 05c, BWSTR 06n

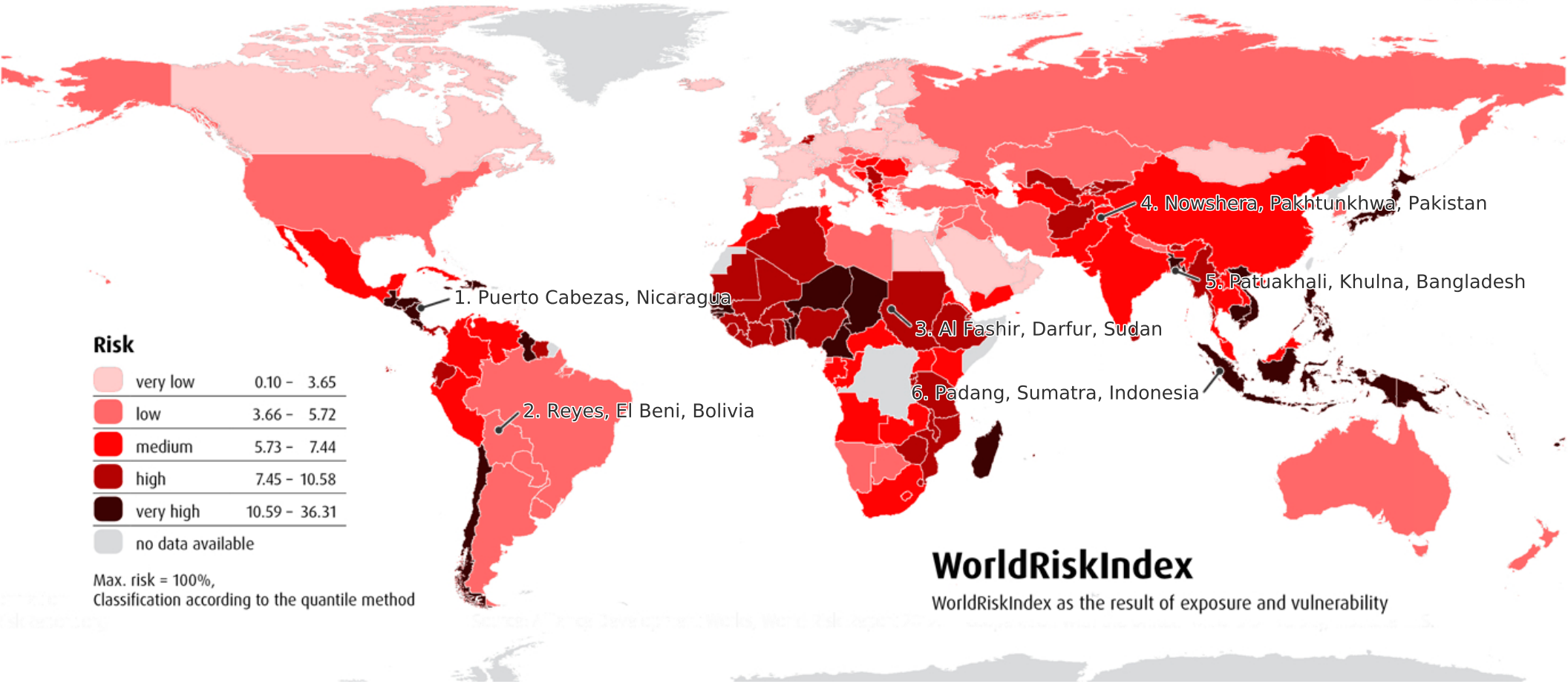
5. Patuakhali, Khulna, Bangladesh
December low/high temp - 15C/26C
April low/high temp - 24C/33C
Annual precipatation - 2712 mm
Avg windspeed - 13 km/h (20 km/h in August)
UV index (July) – 11-14 +
Suggested colour - light orange, light red, light green, tan, green, red
Advised material - polyethylene, ripstop nylon, PVC-coated polyester
Proposed shelter type - BWSTR 02s, BWSTR 06n, BWSTR 07n

6. Padang, Sumatra, Indonesia
November low/high temp - 23C/28C
April low/high temp - 24C/30C
Annual precipatation - 4290 mm
Avg windspeed - 9 km/h
UV index (October) – 12-14 +
Suggested colour – light red, red, white, tan, light green, green
Advised material - polyethylene, ripstop nylon, PVC-coated polyester
Proposed shelter type - BWSTR 06n, BWSTR 07n, BWSTR 08p



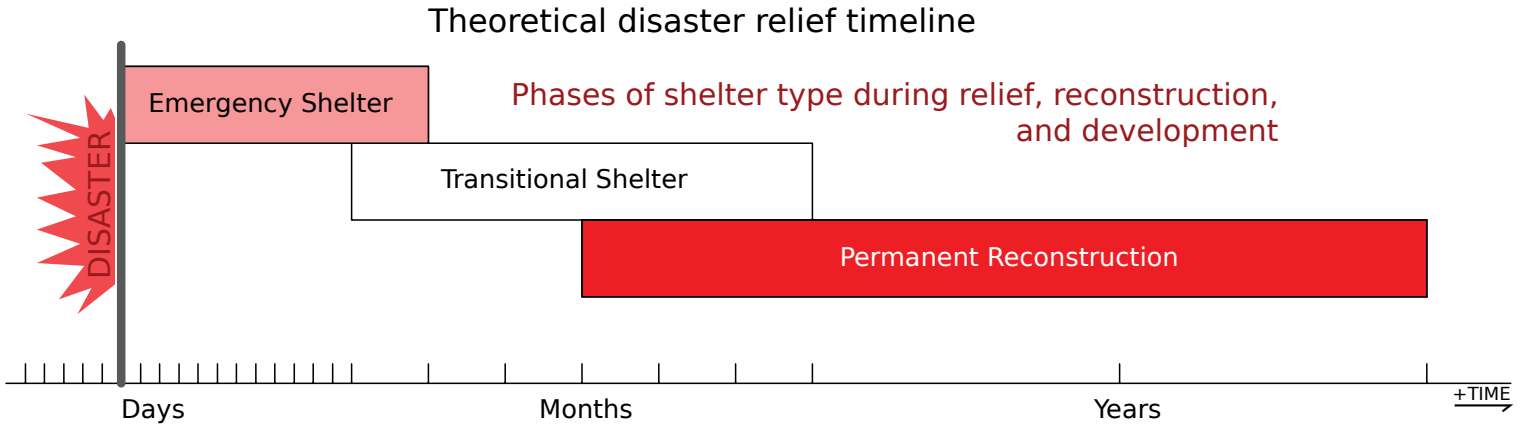

1. Puerto Cabezas, Nicaragua
2. Reyes, El Beni, Bolivia
3. Al Fashir, Darfur, Sudan
4. Nowshera, Pakhtunkhwa, Pakistan
5. Patuakhali, Khulna, Bangladesh
6. Padang, Sumatra, Indonesia




F12

Image F11 (opposite)
A map of the world highlighting the potential regions where BWSTR Series shelters could be deployed. These regions of the planet experience frequent natural disasters.

Image F12 (above)
World regions disaster hazard index indicated by United Nations University Institute for Environment and Human Security. Areas within the medium - very high scale should invest in a stock of emergency shelters. This will mitigate against shelter shortcomings during a disaster response. A reusable emergency shelter system would be a sound investment for these locations.


Theoretical disaster relief timeline
DISASTER
Emergency Shelter
Transitional Shelter
Permanent Reconstruction
Phases of shelter type during relief, reconstruction, and development
Days
Months
Years
+TIME

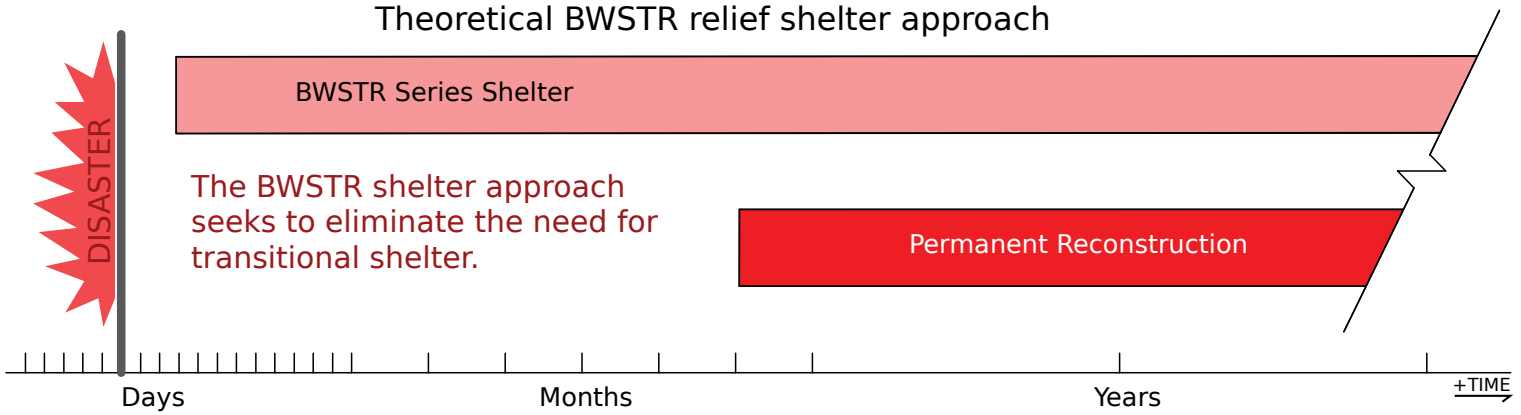

Theoretical BWSTR relief shelter approach
DISASTER
BWSTR Series Shelter
The BWSTR shelter approach seeks to eliminate the need for transitional shelter.
Permanent Reconstruction
Days
Months
Years
+TIME

Fig. 6.09

# Conclusion

Investigating alternative design possibilities can prove to be valuable for humanitarian organizations working within the realm of light-weight emergency relief shelters. The current standard approach to shelter design does not appear to be effective from the beneficiaries' point of view, as the lifespan of the shelter may only last up to one year. Unfortunately, for a large proportion of major disasters, this shelter lifespan is insufficient. The BWSTR Series shelter has the potential to be an economical and durable shelter solution that will eliminate the need for a transitional shelter phase during the process of recovery following a disaster.

Thesis research supports the hypothesis that a light-weight emergency shelter solution can be designed and manufactured to improve upon the current contemporary emergency shelter options. The BWSTR Series emergency shelter solution presented within this thesis was designed to be competitive with the contemporary tent options offered by notable humanitarian organizations. Materials that have developed within the last 40 years have allowed designers to start utilizing synthetic fabrics that have more durable qualities than organic fabrics. An additional benefit is that many synthetic fabrics are more cost efficient than their organic counterparts.

Fig. 6.09 (opposite)
This graph contrasts the current phases of disaster response through reconstruction with a two phase system utilizing the proposed thesis shelter.

The BWSTR Series emergency shelter proposed inside this thesis have skins that may last well over five years. The canvas and PVC-coated fabric models have the potential to last up to 2-5 years depending on storage methods and damage repair. The materials selected will have the capabilities of surviving strong winds (this does not include projectiles within the winds associated with typhoons or hurricanes).

BWSTR models that specify the use of polyethylene sheeting or ripstop nylon do not possess durability characteristics. Although these fabrics are light in weight, they offer little protection to punctures, wind shredding, and UV degradation.

The trade-off for a more secure and durable synthetic fabric is an increase in weight. This additional weight will increase freighting cost. It may increase the difficulty of shelter construction as well. In the end, it will be up to the humanitarian agency to decide which characteristic of the BWSTR Series emergency relief shelters is their priority. It is the hope that in the near future, cost and weight will not be the most influential factors to humanitarian organizations regarding shelter selections.

The BWSTR Series emergency shelters weigh 51-138 kgs and have a material cost of $24-250 USD (this cost does not reflect the additional cost of manufacturing). It is believed that the frame can last more than ten years and the better shelter skins 2-5+ years. If shelter skins are repaired or replaced when needed and stored properly, there is the potential for BWSTR Series shelters made from robust materials to last at least ten years. If this is true, it would mean that BWSTR Series emergency shelters are more durable than transitional shelters that are non-upgradeable. Depending on manufacturing and material selection costs, the BWSTR shelters are priced competitively with emergency shelters used by humanitarian organizations today. Some material combinations selectable for BWSTR Series shelters are competitive with contemporary emergency shelters.

Strong materials selected for a BWSTR Series model shelter will increase weight significantly. By using very durable materials for a BWSTR shelter, this weight increase will be a small fraction of the weight in materials needed for temporary transitional shelters. Transitional shelter materials weigh well beyond 300 kgs for a 18m² shelter made from wood and galvanized iron. If the current humanitarian industry does not have a problem shipping several hundred kilograms worth of materials for a one-time use, non-upgradeable transitional shelter, maybe there is an appetite to

develop heavier durable emergency shelters. These could replace the transitional phase of recovery altogether.

The thesis design took shape through a series of tests and experiments by way of elimination. Designs that were too complicated or had excessive connectors (designs 1,2,3 in Fig. 5.01) that would increase weight for shipment were also eliminated. A round shelter shape was selected for further investigation, due to its shape strength characteristics and water shedding abilities. A barrel or Roman arch-shape was selected over a Gothic arch-shaped shelter, because the barrel-shape allowed more air to flow inside the shelter during the wind simulation tests. This shape will perform better in warm climate zones.

Warm climate zones between Tropic of Cancer at latitude 40°N and below the Tropic of Capricorn at latitude 40°S were selected as the global area that currently needs a new shelter solution the most. This selection was based on the recent fluctuations in severe weather patterns and increased frequency of severe weather occurrence. Contemporary emergency shelters supplied by humanitarian organizations within these regions have been criticized by beneficiaries as being too hot for habitation due to a lack of sufficient ventilation throughout the shelter.

The extended material deformation test proved the assumptions made about fibreglass material to be correct. Fibreglass will not have a curved deformation after being bent for a long time. This will aid in the shipping of the BWSTR Series shelters back to a storage location after beneficiaries have no more need for them. Further testing is required on full-scale model to prove what happened on the small-scale model correct (a full-scale piece of fibreglass pipe was unavailable at the time of the testing). Plastics were not tested because they were not strong enough materials to be considered for shelter frame use. Carbon fibre was not tested because it is too expensive to be used as a frame material.

The design of the BWSTR shelter allows for simultaneous strength and efficiency. Straight pipe members are bent forming a half-arch and then overlapped on top of one another (Image E18). After the shelter is no longer in use and is dismantled, the bent frame pipes relax back to their original straight shape. Utilizing this design will eliminate flat and peaked roofs as options. Peaked roofs will require connector pieces that would allow the framing members to connect to one another at various angles. Using connector pieces will increase shipment weight. Custom connector pieces are also hard to replace if they become damaged or missing.

The final design of the BWSTR shelter had 17.9m² of interior floor space. Sphere Standards states that a minimum of 3.5m² floor space should be provided per person and recommends a 18m² shelter (both emergency and transitional) to accommodate five people per family. These are suggested minimums and are to be followed as rough guidelines. The 18m² shelter size was selected as the design size, because many of the emergency shelters used by humanitarian organizations have floor ares much smaller than this. It is disappointing to know that large families of 5+ (even to 10+) are sometimes only given one shelter to house their family. BWSTR shelters can butt up to each other, end to end, which could double the amount of livable floor space.

At present, the humanitarian community is placing too much confidence on the "tarp as shelter" approach. Although this option is extremely economical and the material appears to be robust, they tend to fail before the predicted lifespan. No beneficiary reacts positively after receiving a large piece of polyethylene to use as a shelter.

In response to this issue, it is justified to allocate donation funds to more durable shelters and the development of more robust solutions. Tents can be rapidly deployed and erected quickly. They offer walls and a roof when compared to sheets of polyethylene that have none of these attributes. Tents are preferred shelter solutions by beneficiaries as well. The demand for tents/ light-weight emergency shelters after a disaster will continue to exist well into the future.

While there are many benefits of an improved shelter design, for instance, increased

durability and cost effectiveness, the reason for these improvements should be emphasized. The core purpose of these improvements is to provide protection and safety for the vulnerable family. This protection can take on many forms, designs, and use various materials. It may be a continuous upgrading process, or a product designed for immediate use. The end goal remains the same. That goal is to provide sufficient shelter for those who have experienced trauma in the form of a disaster and have lost their own safe dwelling.

These shelters provided by humanitarian organizations may not be able to replace what the family has lost, however, they should provide them with an adequate standard of shelter. Adequate shelters should be defined by a sense of safety and security, as well as a sense of dignity, and a provision of privacy. Those that dwell inside adequate shelters should not have to worry when the wind blows or the rain falls.

As the Universal Declaration of Human Rights, Article 25 states:

"Everyone has the right to a standard of living adequate for the health and well-being of himself and of his family, including food, clothing, housing and medical care and necessary social services, and the right to security in the event of unemployment, sickness, disability, widowhood, old age or other lack of livelihood in circumstances beyond his control."[1]

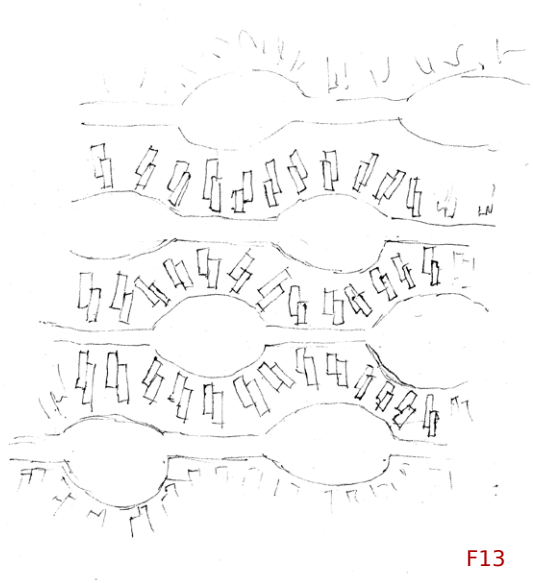
It is unclear how the humanitarian sector defines the term "adequate". By definition, "adequate" means suitable or sufficient and can be replaced with synonyms such as: unobjectionable, capable, acceptable, and decent. A uniformly accepted definition of the term 'adequate shelter', with clear distinguishable characteristics will benefit the entire humanitarian community. Perhaps, the 'minimum' standard of shelter would then progress above rudimentary protection.

Adequate shelters provide a dwelling that is beyond the minimum.

# Epilogue

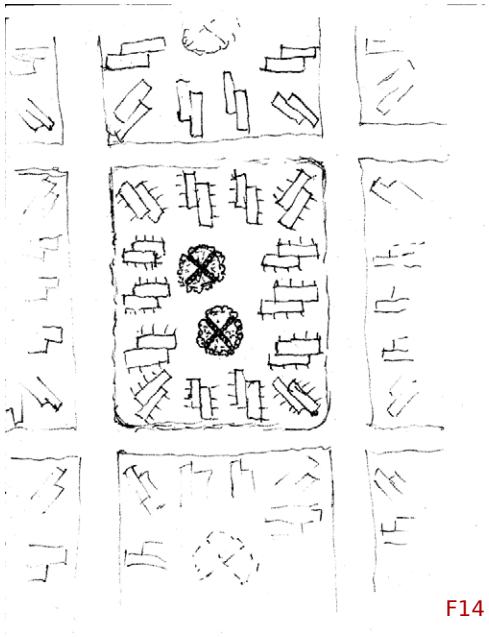
The emergency shelter presented within this thesis is far from perfect. If there were no restrictions on a budget for the BWSTR (short for bowstring) shelter program, many of the low number scores on Fig. 6.08 (pgs 144-146) can be turned into 5's (highest mark). Materials such as carbon fibre or graphite could be used as framing members and fabrics like silicon or PVC-coated Teflon could be used. The use of these materials could potentially extend the life of BWSTR shelters an additional ten years, and reduce shelter weight significantly. Such materials are ballistics rated, which would increase the security effectiveness of the shelter. In the future there may be many alternative synthetic fabrics that perform better and cost less than materials specified in this research.

During the thesis defense, the evaluators noted that the thesis shelter design had a social advantage over many other emergency shelter designs currently used in the humanitarian field. The BWSTR Series shelter has both front and back covered areas for sitting. This covered space can be used for sitting while avoiding th sun's intense rays, or it could be used to wash foods and prepare meals. Both of these activities could help promote a sense of community within temporary shelter camps. The shelters can be laid out either facing each other in the front or facing each in the back. When the shelters are arranged facing each other in the front (Image F13), this may promote a "communal watch" type of atmosphere. People will hopefully warn their neighbours if someone is acting "suspicious" within their camp.



F13

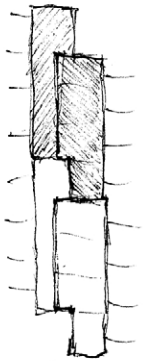
If the shelters are arranged with the back of the shelters facing each other (Image F14), this may help foster a sense of community as well. The shelter is intended to have cooking and meal preparation happen toward the back of the shelter. This might help promote a community that cooks together. People may share ingredients and meals with one another. The camp community might even share the cooking duties for a communal meal.



F14

It is unknown if either of these social conditions would happen from adding a covered space in both the front and the back of the shelter, however, the potential for such outcomes does exist.

It was also noted by the examination panel that there is a potential within the current thesis design for size expansion of the BWSTR Series shelter. The easiest expansion of the BWSTR Series shelter is to assemble two shelters front to back connecting them linearly (Image F15). This would increase the living capacity of the shelter from five people to ten people. However, this is not the only way the BWSTR Shelters can expand. If materials are combined from two or more shelters, there are many design options (Image F16) to expand the livable space within the shelter. These options must be researched further in order

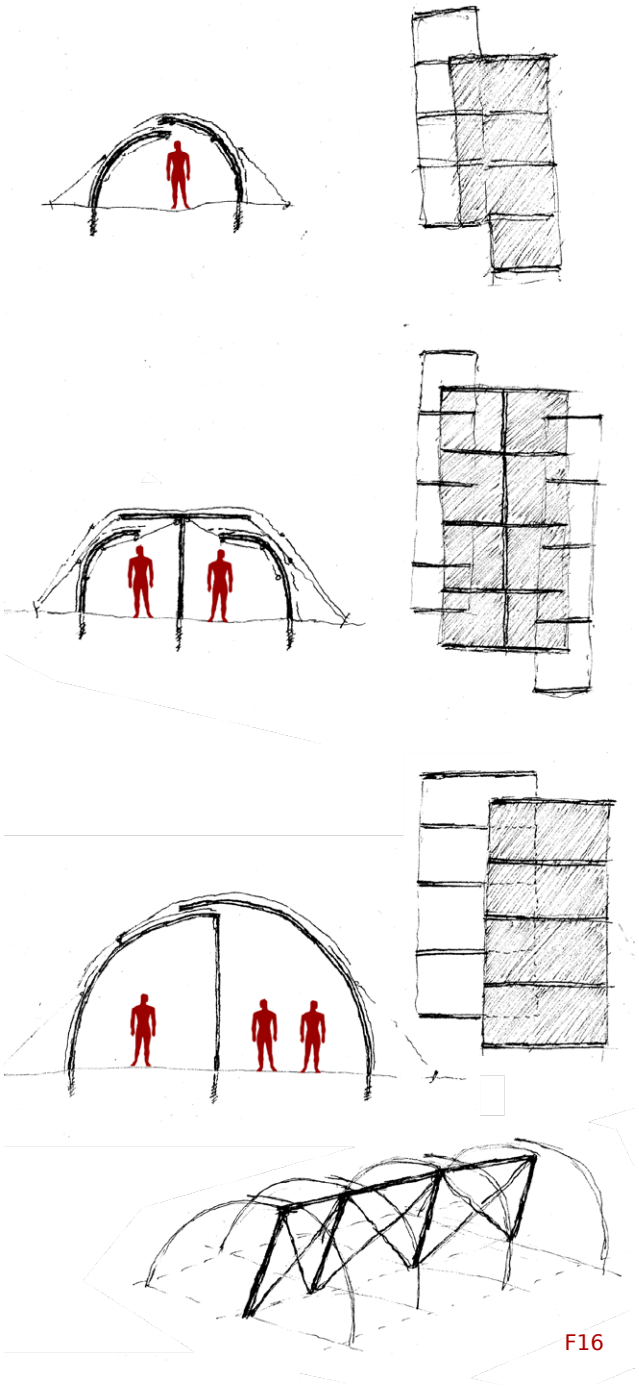


F15

to find the safe design limitations of the materials used. Determining how many expansion options are possible with the materials used in a BWSTR Series shelter might be the subject of another thesis.

This study was limited by a lack of funds. If a second attempt was made in this study, a full-scale model would have been produced for actual results. It is difficult to know whether or not assumptions of the shelter assembly process are correct as well.

Applications to academic grants will help fund prototypes for further research. A physical model is needed to prove or disprove this shape as a successful candidate for use as an emergency relief shelter. Writing to Canadian International Development Agency (CIDA) and Canadian Council for International Cooperation (CCIC) to ask if developing a prototype BWSTR Shelter falls within their funding criteria is a very important step. Funding from CIDA/CCIC would ensure the forward progression of the BWSTR Shelter.



F16

Other resources and non-profit organizations with research funding attainable are: The Honda Canada Foundation, The Bill and Melinda Gates Foundation, Social Sciences and Humanities Research Council Canada (SSHRC), Center for Disaster Management and Humanitarian Assistance (CDMHA), Department for International Development (DFID) (UK) (Humanitarian Assistance), Rotary Foundation, U.S. Agency for International Development (USAID), and many others. These charitable and non-profit organizations have funding available to organizations that deal with disaster-relief operations. It is unclear if this funding from such organizations would go toward disaster-relief shelter development. Writing to these organizations and asking them if shelter prototyping fell under their qualifications for funding is the next logical step.

Ideally, two prototypes should be made. A shelter should be sent to directly to the National Research Council Of Canada Laboratories (NRC). The NRC will be able to test full a full-scale

Image F16 (centre)
The top of this image shows the standard BWSTR Series shelter. The middle illustration shows a potential design if 2 BWSTR shelters were combined. The bottom illustration in this series hints at the large shelter possibilities using the BWSTR Series shelter framing materials.

model in wind tunnels, material strength testing, and optional fire testing. A research facility of this magnitude is not common on university campuses. During the testing process, there is an opportunity for continued design development. The second prototype will test physical properties of the shelter. Design improvements will result from the process of transportation, assembly, and disassembly.

Around this time, an application should be made to Canadian Intellectual Property Office (CIPO) to patent the shelter design. This application will require an abstract, specifications, and drawings. The abstract is a brief description of the invention, while the specification is a detailed description of the invention, its usefulness, and claims that define the boundaries of patent protection. Drawings are to be included that will assist in describing the invention visually, as well as aiding the specifications with technical diagrams. It is unknown how long this process will take.

After prototyping and full-scale NRC analysis has been completed the shelter must be tested within the field. Several shelters must be manufactured and shipped to various locations across the globe where frequent natural disasters occur. A variety of skins should be included in the shelter package. Skins should be changed after a specific period of time in order to record/analyze how each skin option reacts to various world locations and climate zones. Additionally, the level of human comfort should be recorded by the research committee. The results from these tests will be used to improve the shelter design. Ultimately, the information gathered will be used to create a product that can be manufactured at scale.

With the development of a product like the BWSTR Series emergency shelter, there is the potential to partner with both for-profit and non-profit organizations. Non-profit humanitarian organizations such as: Oxfam International, International Committee of the Red Cross, International Federation of Red Cross and Red Crescent Societies, United Nations Human Settlements Programme, United Nations High Commissioner for Refugees, CARE International, Habitat for Humanity International, Médecins sans Frontières, World Vision International, and many more might show interest in this emergency shelter design. These organizations may help test the BWSTR Shelters in the field. If the field testing shows positives results, there may be the potential to receive funding from these organizations for further development.

For-profit companies in the private sector involved with transportation (Fed-Ex, UPS, Air Canada, American Airlines, etc.) may help in the development of refining the transportation method of the BWSTR Series shelters possibly at no extra cost. Companies in the material development industry (DuPont, Owens Corning, 3M, Dow, Dow Corning, etc.) should be contacted as well. If there is enough demand, there could be the potential to develop new fabric materials, specifically for the emergency shelter industry. The private sector may require exposure in news articles for their charitable deeds and may request product logos on the BWSTR Series prototype shelters.

The partnership outcomes listed for both non-profit and for-profit partnerships are only speculations. It is uncertain how either industry would engage with partnership proposals involving the development of BWSTR Series shelters.

The overall intention of this study was to improve upon disaster-relief shelter designs. Theoretically, it is now known that shelter design presented by this thesis does have the potential to improve living conditions for those affected by a natural disaster (and man-made disasters within the specified temperature range). Hopefully, in the future people will have the opportunity to live in these shelters post-disaster. The BWSTR series shelter will usher in a new trend of socially conscious disaster-relief shelters that surpass minimum shelter standards and improve quality of life.

## CONCLUSION

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# APPENDIX

# Material Cost Sources

Company: SuQian XinBao tarpaulin co.,ltd
Product: 18oz 610gsm truck cover (Raw material:100% Polyester with PVC coated Denier:1000D*1000D Yarn density:20*20/inch Weight:500gsm-800gsm Thickness:0.4mm-0.7mm)
Preferred minimum: 3000sqm
Cost with shipping: $6000, $2 per sqm, 3.2m x 50 rolls, or as ordered example: 2m x 30m roll
Minimum special case: 3.2m x 21m roll – cost $250, shipping $300, total $550

Company: Shanghai UNISIGN industrial material co., ltd
Product: UCT1122/610 Coated PVC tarpaulin 1000*1000D, 20*20/sq.in 610gsm (rolls of 50m or 100m - 3.2*50=160sqm, or 2*50=100sqm)
Preferred minimum: 3000sqm
Cost: FOB Shanhai $1.66 per sqm, $4980@3000sqm
Seafreighting the minimum: $3900 usd
Cost with shipping: 4980+3900=8800 ($2.96 sqm)
* 20 ft container capacity – 35000 sqm

Company: Nanjing Able Composite Co.,Ltd
Product: diameter 1.25'', wall thickness 3mm, diameter 1.50'', wall thickness 3mm pultrusion fibreglass pipe
Preferred minimum: 1500m
Cost with shipping: 1.25" FOB shanghai port price: 1.420 USD/meter, 1.5" FOB shanghai port price: 1.660 USD/meter (lengths from 1m - 5m+)
Shipment cost: $3000 – 4000 (3500)
Cost w/ shipping: 1.25"@1500m – $5630: $3.75m, 1.5"@1500m - $5990: $3.99m

Company: Dongguan Juli FRP Products Co.,Ltd
Product: (carbonfibre) fiberglass veiled tubes,ID1.5",OD1.9" and ID1.25",OD1.6" @ 120cm (extra $ for shipping longer)
Preferred minimum: 500m
Cost with shipping: USD $15.3 per meter for 1.5", USD $11.2 per meter for fiberglass veiled tubes 1.25"

Company: JUTU Technologies Ltd.
Product: PVC Coated Tarpaulin (White) JTP1020 1000D*1000D 20*20 610g/sqm, 3.2m x 50m roll - $1.674 USD/sqm, JTP1014 1000D*1000D 14*14 610g/sqm, 3.2m x 50m roll - $1.375 USD/sqm
Preferred minimum: 60 rolls – 9600 sqm
Shipping: 60 rolls total volume is around 8.07 cbm and total gross weight is 6048 kg. It is just more than one quarter of one 20 feet container. Cost to Toronto this time is around 110 USD/cbm and plus AMS 25 USD.
Cost with shipping: 60 rolls of JTP1020 - $17,159.45 ($1.787 USD/sqm), 60 rolls of JTP1014 - $14,289.45 ($1.488 USD/sqm)

Company: Jinan Golden Bull Canvas Textiles Co.,Ltd
Product: Flame retardant 18oz Pvc coated polyester, 600D*900D, 600g/sqm, density 40*30, 3.2mx50m per roll, any colour
Preferred minimum: 60 rolls - 9600sqm
Cost with shipping: $320/roll CIF Toronto, $320x60=$19200 CIF Toronto, $2 USD sqm
Also: 400gsm - $208/roll(3.2mx50m/roll) MOQ:60rolls
Total Sum:$208x60rolls=$12480 CIF Toronto

Company: Ningbo Solid Insulating Products Factory
Product: carbon fibre ID 31-32 * OD 39-40 * L 1500MM unit price is USD $13.58, carbon fibre ID38-40 * OD46-48 *L1500MM , unit price is USD $14.92
Preferred minimum: 500pcs
Cost with shipping: $9.05 per m, $9.95 per m

Company: Laizhou Lutong Plastics CO.,LTD
Product: 6mm white nylon solid braid rope, 10mm solid braid rope
Preferred minimum: 6mm – 300 coils (100m per coil, 1.7kg per coil), 10mm – 200 coils (100m per coil, 3kg per coil)
Cost: 6mm - FOBQINGDAO USD 6/Coil, 10mm FOBQINGDAO USD 10/coil
Cost with shipping: 6mm - CIF Toronto, Canada USD 6.68/Coil ($0.0668 per m) 300 coils: $2004, 10mm - CIF Toronto, Canada USD 11.2/Coil ($0.112 per m) 200 coils: $2240

Company: Wintech Group Co., Ltd
Product: 6mm white nylon braid rope (40m/kg), 10mm braid rope (15.8m/kg)
Preferred minimum: 6mm – 40,000m, 10mm – 15,000m
Cost without shipping: 6mm - $0.17/M, 10mm - $0.40/M
Shipping: $450 on min. order

Company: Wintech Group Co., Ltd
Product: 60mm x 60mm mesh size 3mm PE rope netting (100m x 500m size)(0.41kg per sqm)
Preferred minimum: 1000kg (2,439sqm)
Cost without shipping: US $ 2.9-5.5 per kg ($2900 min order - $1.19 USD per sqm)
Shipping: unknown

Company: HangZhou GenZhou Import&Export CO.,LTD
Product: GZ-CF-110 - 200 rolls in widths of 1.5m, 2m, and 3.2m - colour white
GZ-CF-550 - 200 rolls in widths of 1.5m, 2m, and 3.2 m -colour white
Price: GZ-CF-110 – 200 rolls @ $1.56usd/sqm, GZ-CF-550 - 200 rolls @ $1.47usd/sqm
Preferred minimum: 30 rolls
Preferred shipping requirements: 1.5m *50m quantity of 1 container is 445 rolls, LCL the quantity needs to be 8000sqm of each weight
Shipping cost: not given

Company: Nantong Helia Plastic Co., Ltd.
Product: PVC coated fabric 600d 3.2m*50m roll
Preferred minimum: 3000 sqm
Cost: USD $2.6 per sqm, FOB Shanghai ($7800 min order - 19rolls)
Shipping: unknown

Company: YIWU LIRUO WEBBING CO.,LTD
Product: 300D Polyester 25mm wide, 0.7mm thick strapping (white or black)
Preferred minimum: 5000m
Cost: $0.1 USD/m ($500 per 5000m)
Cost with shipping: unknown

Company: Nanjing Omite Transportation Equipment Co., Ltd.
Product: BT-25 – 25mm, 15000N System tension force, 7850N Section tension force9, polyester cord strap, 1 roll is 450m
Preferred minimum: 1 pallet - (2 rolls/box and 36 boxes/pallet)
Cost: $0.138 per m, $62 per roll, $124 per box, $4,464 per pallet
Shipping: 1 pallet - $250 to Toronto

Company: Shanghai Topack Logistics Equipment Co., Ltd.
Product: 25mm polyester woven lashing's minium linear breaking strength is 1000kg-1350kg, and its Minium system breaking strength up to 100-2160kg, packing: 500meter/roll, 2 rolls per box
Preferred minimum: 1 20ft container (900 rolls approx)
Cost: $198 per box (2 rolls), $0.198 per m, $89,100 per container (unconfirmed)
Shipping: cost of transporting a 20ft container
Product requested: 3000m
Product w/ shipping to Toronto: $2400 USD for 3000m - $0.8 per m

Company: Hebei Yuntao Trading Co., Ltd.
Product: Galvanized Steel Wire chicken wire, SWG20 (20 gauge), 1m or 2m widths (2" mesh - 50m * 1.22m height = 16kg – 0.32kg/m .26kg/sqm, 1" mesh – 50m * 1.22m height = 24kg – 0.48kg/m) PVC coating adds 6kg to 1" mesh 50m roll and 3kg to 2" mesh roll 50m.
Preferred minimum: 5000 Square Meter/500 rolls
Cost: US $ 0.18 Square Meter ($900 min. order)
Shipping: unknown

Company: Xiamen Longtaixing Garment Co., Ltd.
Product: 200gsm-400gsm waterproof canvas
Preferred minimum: 800m of 60/120" rolls
Cost: $1.78 USD/m (unverified)

Company: Xiamen Longlasting Garment Co.,ltd
Product: Grey Canvas fabric, 35%cotton,65%polyester, width is 1.6m
Preferred minimum: 800m
Cost: 300gsm,price will be USD $1.7/m ($1.06 per sqm)Fob China, 400gsm,price will be USD $1.98/m ($1.24 per sqm)Fob China.

Company: Wintech Group Co., Ltd.
Product: white nylon 3/8" rope
Preferred minimum: 1000kg (61 - 1200' rolls = $10,072.32)
Cost: $0.45 per m (1200' roll of 3/8" line - $165.12, )

Company: Shanghai Civil & Road Instrument Co., Ltd.
Product: 1m soil sampler auger
Preferred minimum: 5
Cost: $110 per auger
Shipping: unknown

Company: SUNGBO E&T
Product: 19mm Dia 400mm long aluminum spiral tent peg
Preferred minimum: 500 pieces
Cost: 4 for $5 USD ($1.25 each)

Company: Dingzhou Huaxing Wire Mesh Factory
Product: 5/16" dia 16" ground corkscrew, weight – 0.72kg
Preferred minimum: 20,000 pieces (50/box)
Cost: FOB China $0.2 - $1.0 a piece
Shipping: unknown

Company: Huanghua Juhong Hardware Products Ltd.
Product: 5/8"X4"X30" (dia 16mm, 4mm thick) iron earth anchor, weight - 1.766 kg
Preferred minimum: 20 tons
Cost: $2 USD (assume FOB China)

Company: Decorstainless International Co., Ltd.
Product: 316 stainless steel rope cleat
Preferred minimum: 10 pieces
Cost: $0.10 USD if 100 pieces ordered.
Shipping: unknown

Company: Montana Canvas
Contact: http://www.montanacanvas.com/products/rope-tension-adjusters
Product: guy rope tensioner
Preferred minimum: n/a
Cost: $3 USD per 12 ($0.25/per)

Company: Feicheng Haicheng Plastic Package Co., Ltd.
Product: PE blue tarp rolls, 2m width, 60-270g/sqm
Preferred minimum: 5 tons
Cost: $0.1 per sqm

Company: Hui Quan Plastic Tarpaulin Factory Of Weifang
Product: PE tarp, width 1.8m/2.1m/4.8m/5.6/7.2m, 60gsm-300gsm
Preferred minimum: 10 tons
Cost: less than $0.01 per sqm

Company: Suqian Xin Bao Tarpaulin Co., Ltd.
Product: 500GSM, 300D, 20*20, PVC coated polyester, width 1.3m , 1.5m , 1.8m , 1.9m , 2m , 4m ,6m
Preferred minimum: 2000m
Cost: US $ 1 - 1.6 / sqm

Company: Suqian Xin Bao Tarpaulin Co., Ltd.
Product: 750GSM, 900D*900D, 20*20, PVC coated 2 sides polyester, width 1.3m , 1.5m , 1.8m , 1.9m , 2m , 4m ,6m, thickness 0.6mm, roll length 10m, 50m, 100m
Preferred minimum: 10000m
Cost: US $ 1.2 - 1.5 / sqm

Company: Suqian Xin Bao Tarpaulin Co., Ltd.
Product: 560GSM, 600D*600D, 20*20, PVC coated polyester, width 1.3m , 1.5m , 1.8m , 1.9m , 2m , 4m ,6m, thickness 0.3mm, roll length 10m, 50m, 100m, flame retardent
Preferred minimum: 2000m
Cost: US $ 0.9 - 1.5 / sqm

Company: Suqian Xin Bao Tarpaulin Co., Ltd.
Product: 800GSM, 1000D*1000D , 20*20, PVC coated polyester, width 1.3m , 1.5m , 1.8m , 1.9m , 2m , 4m ,6m, thickness 0.6mm, roll length 10m, 50m, 100m, flame retardent, model TM-419
Preferred minimum: 2000m
Cost: US $ 1.1 - 1.8 / sqm

Company: Xiamen Xin Jie Feng Co., Ltd.
Product: 25mm strapping
Preferred minimum: PP 900D 8000m and Polyester 12000m
Cost: 25mm 900D PP webbing black color is $0.049usd/m,white color is $0.074usd/m. 25mm polyester is $0.104usd/m. FOB Xiamen.

Company: Shaanxi Tiangong PTFE & Plastic Meterial Development Co.,Ltd
Contact: Irene
Product: PTFE pipe
Preferred minimum: unknown
Cost: $6.4USD/M the length is 1M/pcs

Company: Shen Zhen Hing Tat Yick F. R. P. Products Ltd.
Product: fibreglass pipe 37mm OD x 33mm ID x 2mm Wall Thickness
Preferred minimum: 2000m (980kg weight)
Cost: EXW price: $1.71 per meter USD
Shipping: Gross Weight- 980kg Volume- 4.5 CBM Surcharge and Sea Freight to Toronto-880USD
Cost with shipping: $2.15 USD per m

Company: Dongguan SanChuang FRP Products Factory
Product: pultrusion fibreglass pipe OD 40mm,wall thickness 3mm, OD 38mm,wall thickness 4mm
Preferred minimum: unknown
Cost: 1. OD 40mm,wall thickness 3mm, and the EXW PRICE is USD2.15/meter,
2. OD 38mm, wall thickness 4mm, and the EXW PRICE is USD2.57/meter,

Company: Zhengzhou Yalong Pultrex Composite Materials Co., Ltd.
Product: fibreglass pipe ID 30mm, OD 40mm, wall thickness 5mm, 3m length
Preferred minimum: 666pcs @ 3m – 1998m (weight - 2000kg)
Cost: US$3.66 per meter, C&F Toronto

Company: Qingdao Wangbaoqiang Industry Co., Ltd.
Product: model N60*550 ground screw (recommended model WBQ N60*550)
Preferred minimum: unknown
Cost: 3.29 USD/piece FOB Tianjin China

Company: Huanghua Fuyuan Hardware Products Co., Ltd.
Product: ground screw 67x1.8x520mm 1.8kg/pc
Preferred minimum: 2000pcs
Cost: FOB Tianjin :USD 3.46
Shipping: $600 CIF Toronto

Company: Wenzhou He Feng Buttons & Accessories Co., Ltd.
Product: 4.5*25mm metal d ring (0.017kg/pc)
Preferred minimum: 5000 Piece
Cost: $0.01/pc USD

Company: Jinan Golden Bull Canvas Textiles Co.,Ltd
Product: 10s/3*2 0.9m thickness 0.81mm cotton canvas 483gsm, 21s/10*10 1.45m thickness 1.25mm cotton canvas 700gsm
Preferred minimum: 2000sqm
Cost: 10s/3*2 - $2.4/sqm, 21s/10*10 - $5.28/m (3.64sqm)

Company: Shijiazhuang JHR Im.&Ex. Co.,Ltd.
Product: 40mm OD 4mm thick fibreglass pipe, 6m & 12m lengths
Preferred minimum: 2000m
Cost: $2.8/m USD CFR Toronto, Canada (potentially $1.15/m if shipping is $3500)

Company: Shijiazhuang Ningbo Canvas And Tarpaulin Textile Co.,Ltd.
Product: Weight:300g/m2 Width:1.5m 300gsm canvas, Weight:400g/m2 Width:1.5m 400gsm canvas
Preferred minimum: 5000m (7500sqm)
Cost: 300gsm – $2.87/m CNF Toronto ($1.91/sqm, without shipping – $1.44/sqm), 400gsm - $3.20/m CNF Toronto ($2.13/sqm, without shipping - $1.66/sqm)

Company: Cangzhou City Shijiheng Plastics Co., Ltd.
Product: 60L HDPE Blue/white food grade barrel, 410mm dia, 1m height, weight 3.4kg/pc
Preferred minimum: 100/pcs
Cost: $10.16/pc USD

Company: Ningbo Flourishing Import & Export Co., Ltd.
Product: 90L HDPE Volum:90L. Weight:2.7kg. Size:D535mm*H575mm.
Preferred minimum: 500pcs
Cost: $9/pc USD

Company: Taizhou Tianyi Packing Products Co., Ltd.
Product: 25L PP Pail, 340mm dia, 380 mm height, weight 800g (0.8kg)
Preferred minimum: 1000/pcs
Cost: $1.5/pc

Company: Dingzhou Huaxing Wire Mesh Factory
Product: HX4153 galvanized 300mm tent peg (0.1kg/pc)
Preferred minimum: 20,000pcs
Cost: $0.05/pc

Company: Qingdao Allied Machinery Co., Ltd.
Product: 316 stainless eyebolt 1" 1/4" dia
Preferred minimum: 500pcs
Cost: $0.1/pc USD

Company: Shenzhen Huijiaxin Technology Co., Ltd.
Product: polished iron eyebolt 1" 1/4" dia
Preferred minimum: 10,000pcs
Cost: $0.02/pc

Company: Hangzhou Ever Import and Export Co., Ltd.
Product: 3m length 10-150mm dia tonkin bamboo pole 0.188kg/m
Preferred minimum: 25 cubic m
Cost: $0.1 per 3m pole ($0.03/m)

Company: Anji Hong Li Bamboo & Wood Crafts Factory
Product: 0.6-6.4m length 8-160mm dia moso bamboo pole 0.2kg/m
Preferred minimum: 1000pieces
Cost: $0.01/m

Company: Yiwu Itrust E-Commerce Firm
Product: 1kg – 2kg hand-held sledgehammer
Preferred minimum: 500pc
Cost: 1kg - $1USD/pc 2kg - $3USD/pc

Company: Ningbo Assist Tools Co., Ltd.
Product: 18mm utility knife
Preferred minimum: 6000pcs
Cost: $0.3/pc

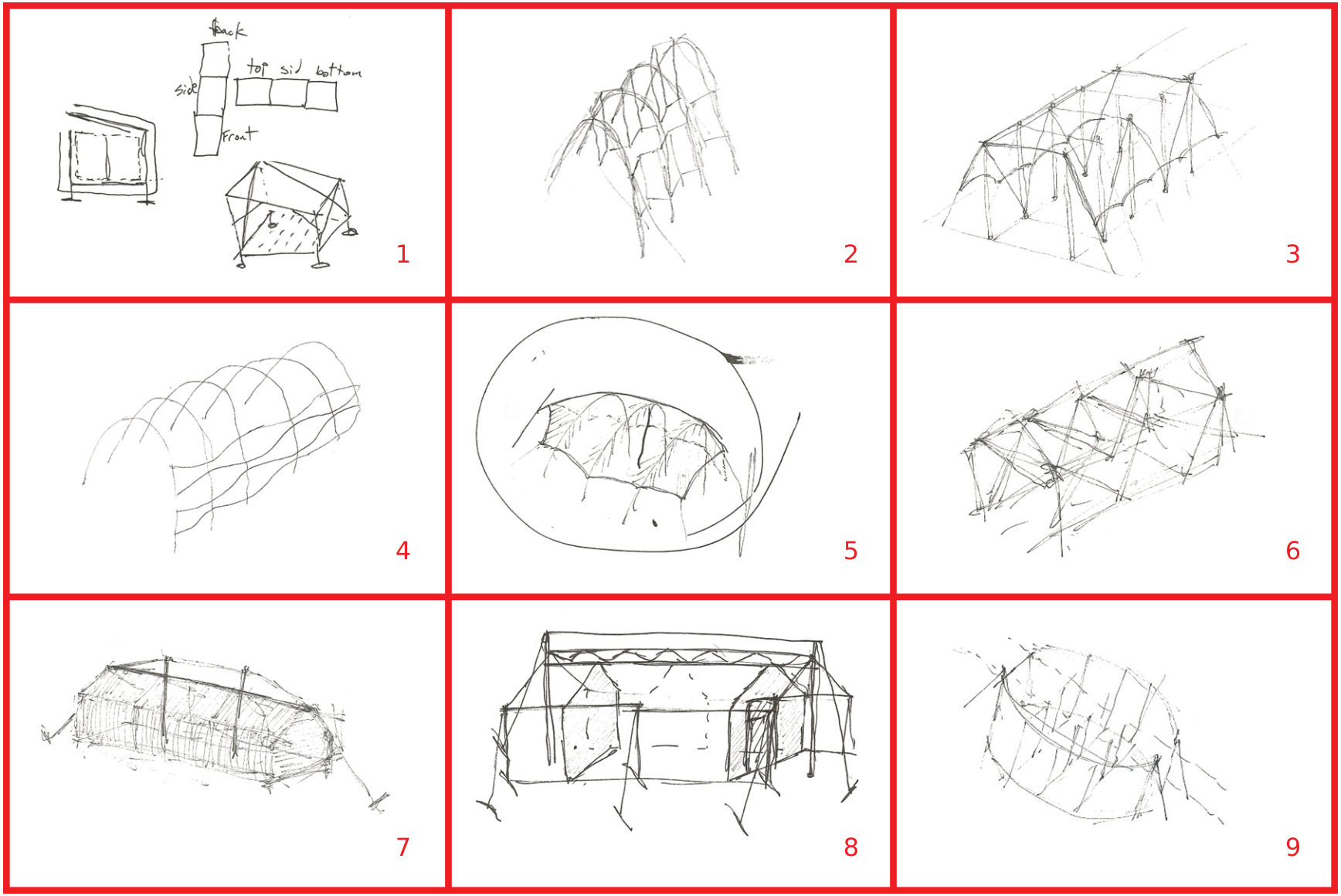
Company: Hangzhou Weigong Hardware Tools Co., Ltd.
Product: 250mm pliers
Preferred minimum: 1000pcs
Cost: $0.9/pc

Company: Wujiang Wanshiyi Silk Co., Ltd.
Product: 180gsm 70D*160D Taslan Waterproof PU coated Nylon
Preferred minimum: 1000/m (58" roll)
Cost: 0.8/m - $0.55usd/sqm

Company: Suzhou Yifan Textile & Clothing Co., Ltd.
Product: 420DX420D 160 gsm nylon oxford
Preferred minimum: 3000m (60" roll)
Cost: 1/m - $0.67 usd/sqm

Company: Green Textile (Wujiang) Co., Ltd.
Product: 70D*(160D+160D*2) 137gsm waterproof ripstop taslan nylon
Preferred minimum: 800 (58" roll)
Cost: 1.5/m - $1.02usd/sqm

# Design Timeline

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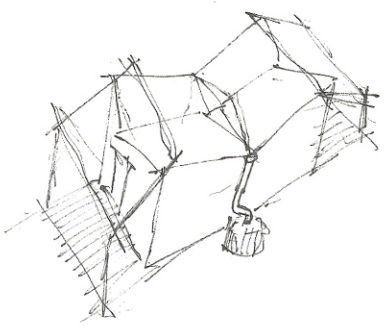

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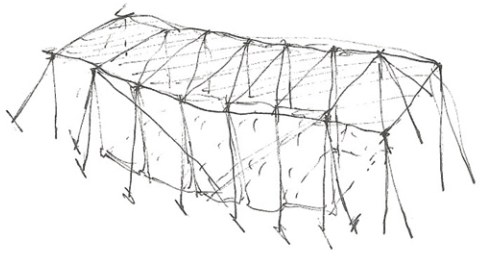

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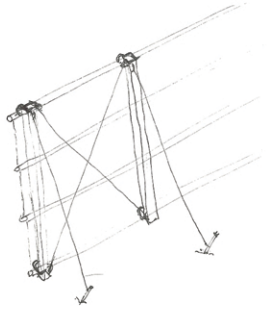

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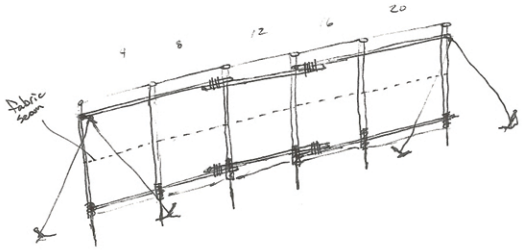

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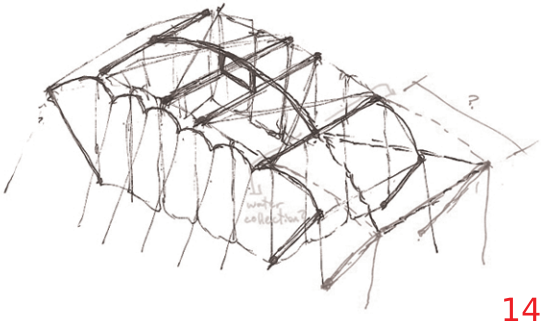

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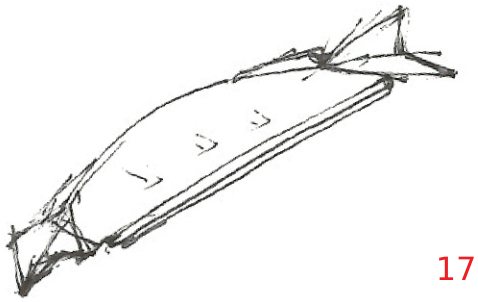

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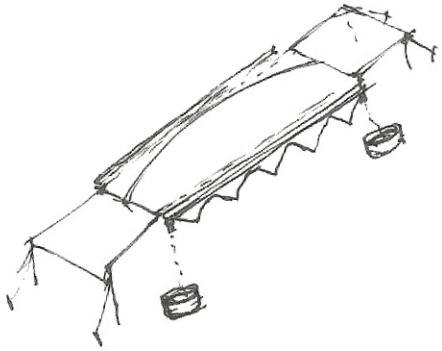

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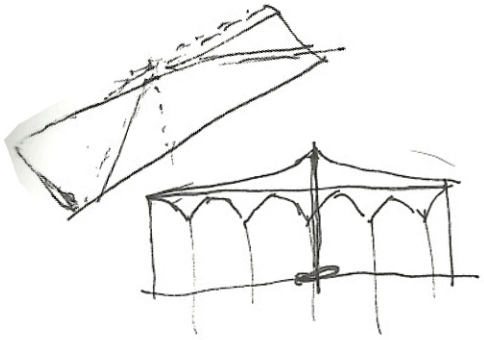
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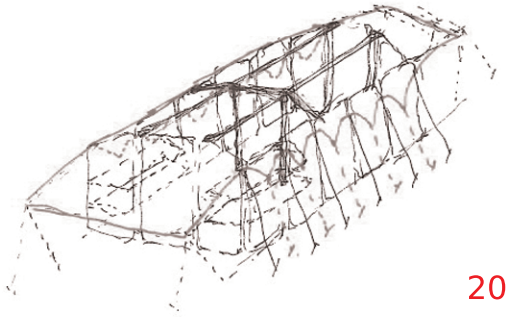
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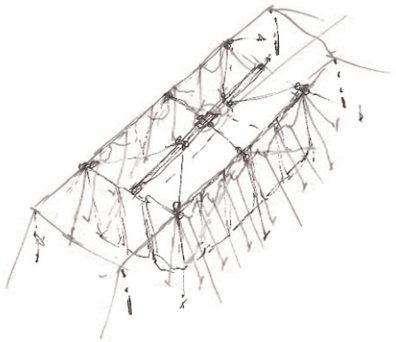
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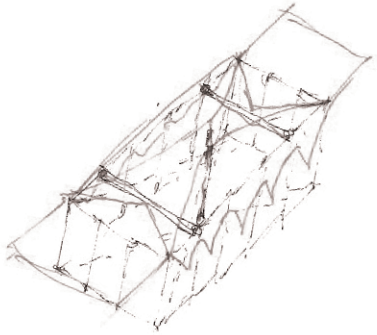
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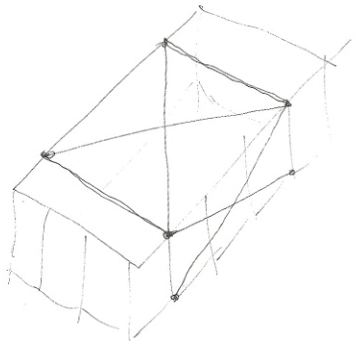
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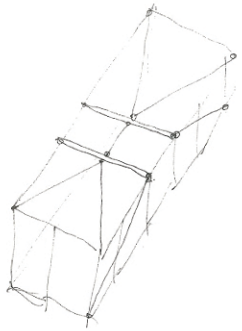
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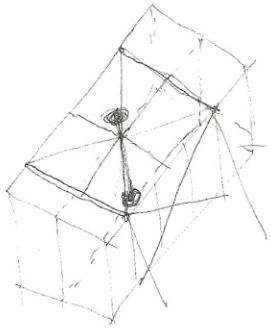
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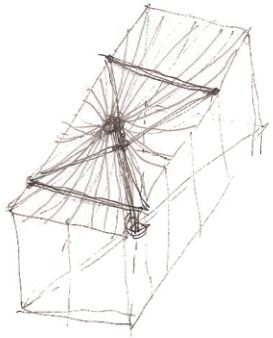
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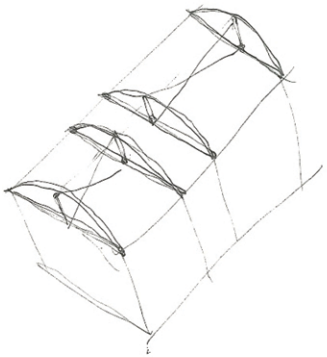
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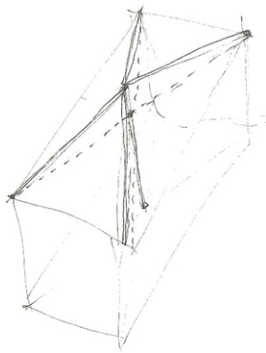
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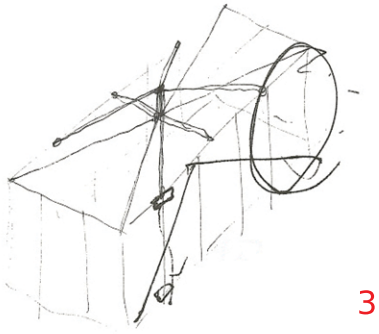
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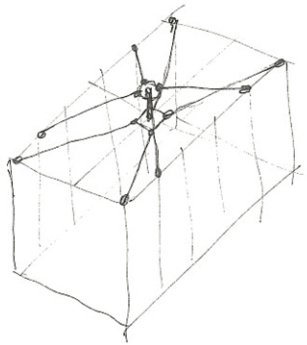
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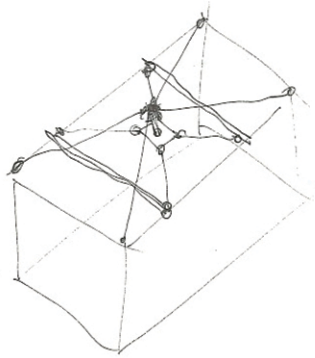
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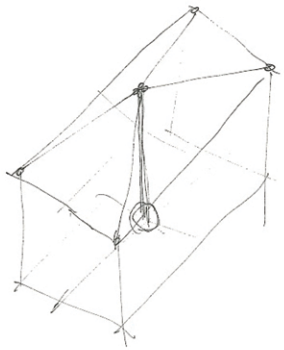
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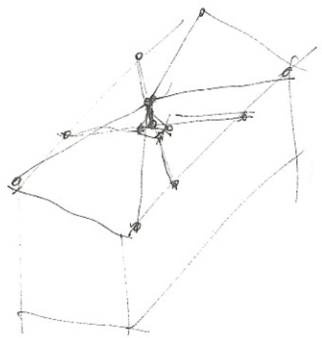
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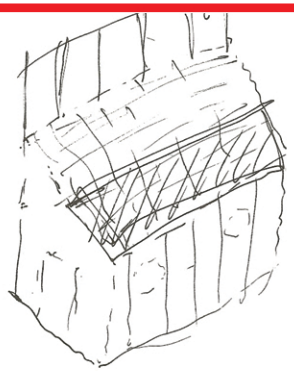
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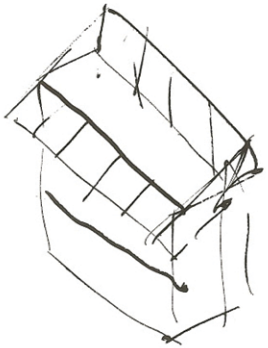

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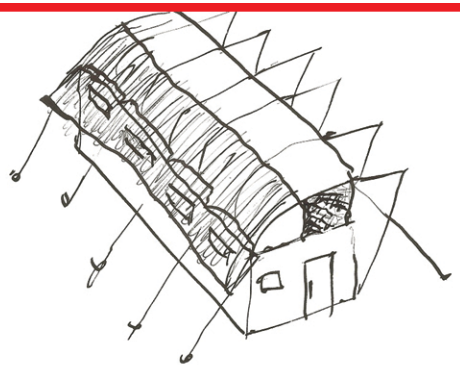

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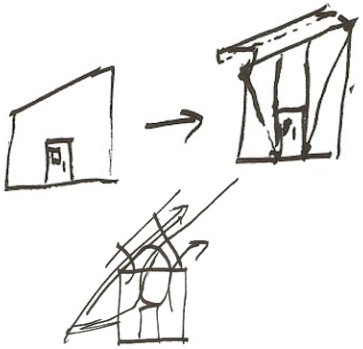

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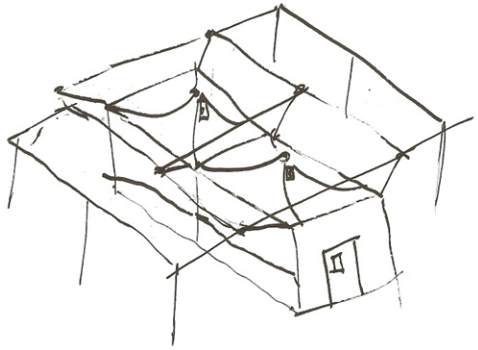

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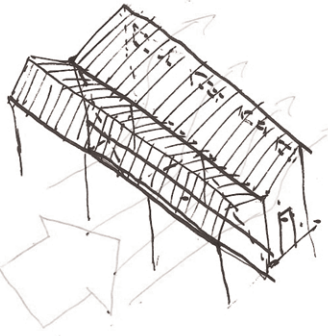

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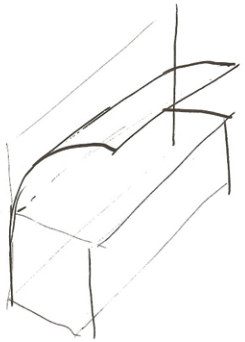

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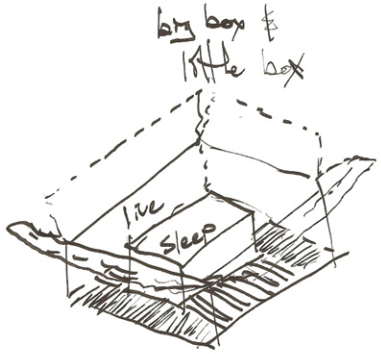


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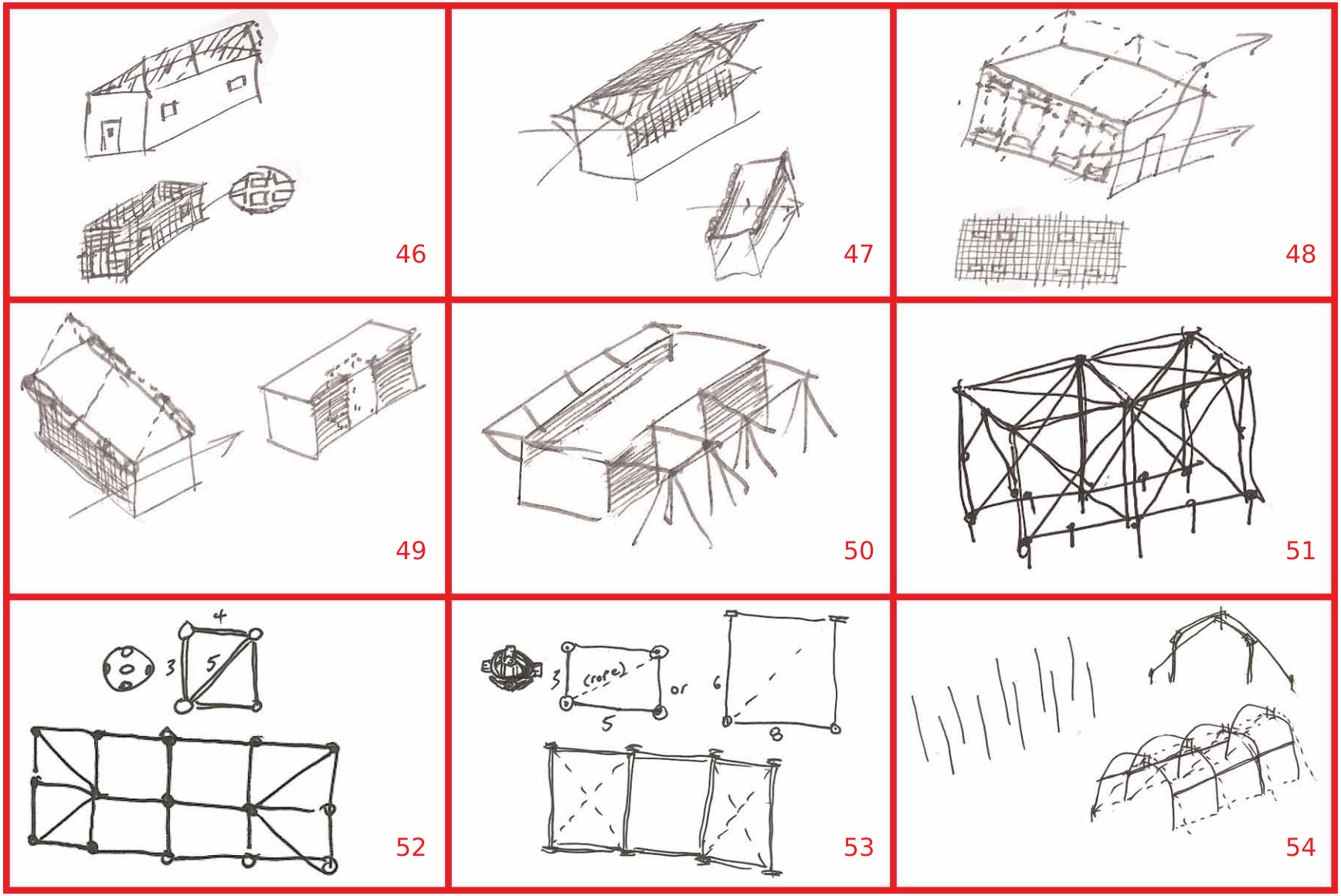


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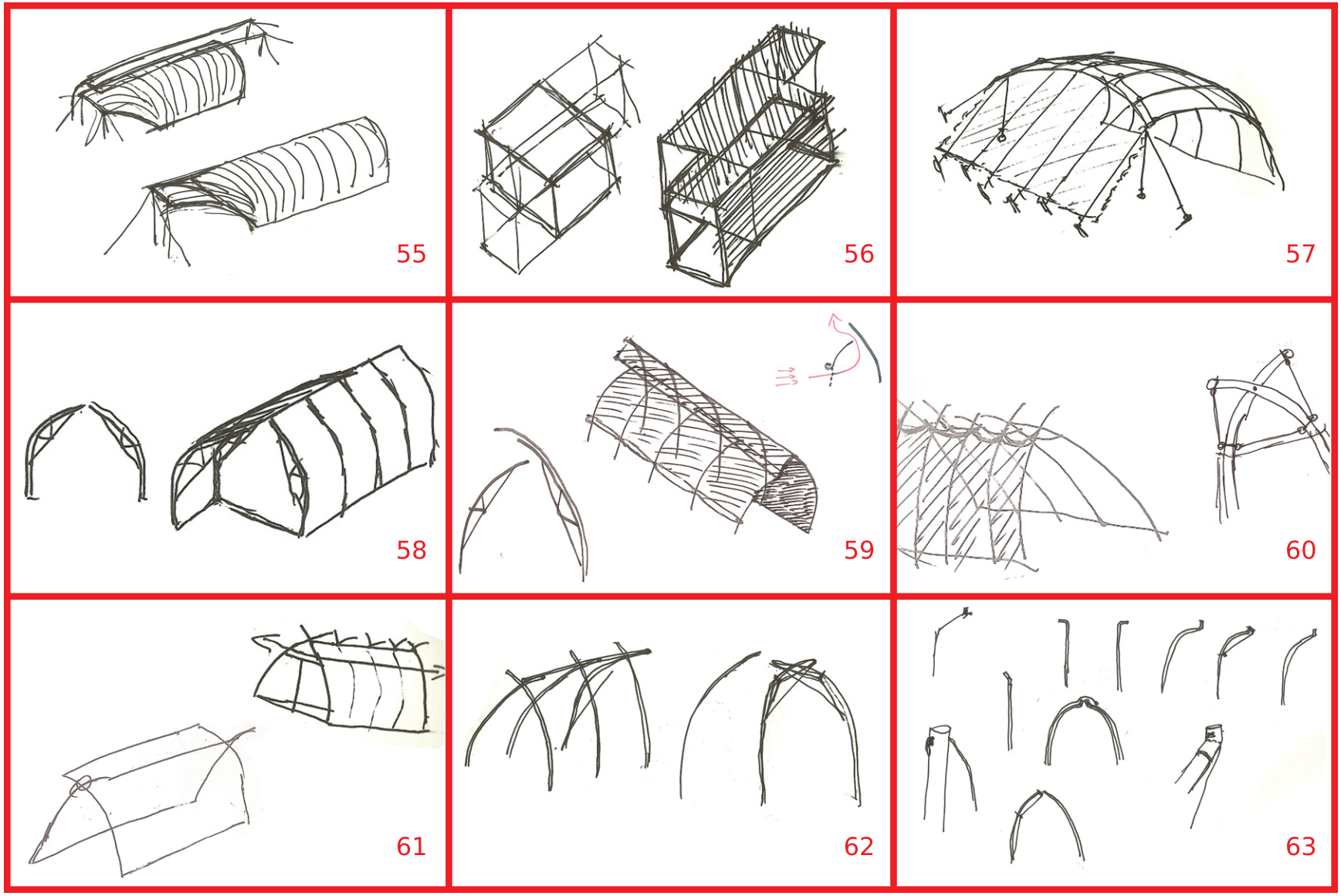


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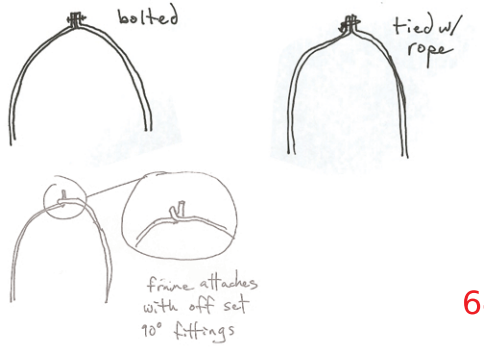


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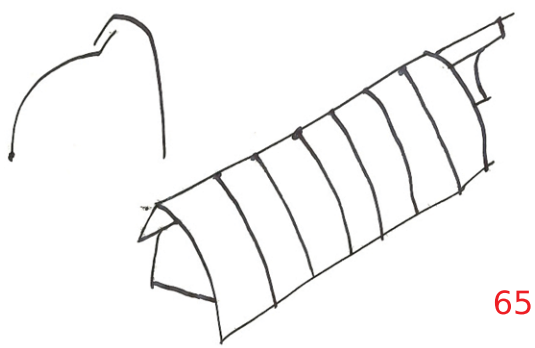

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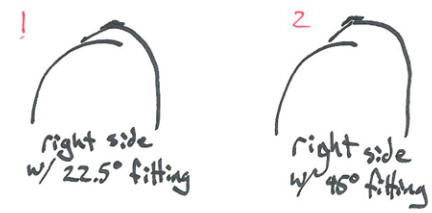


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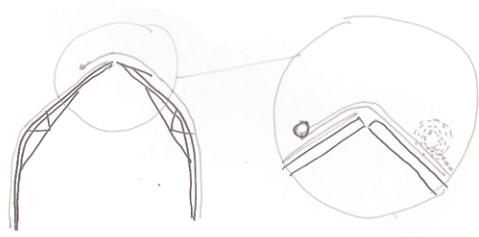

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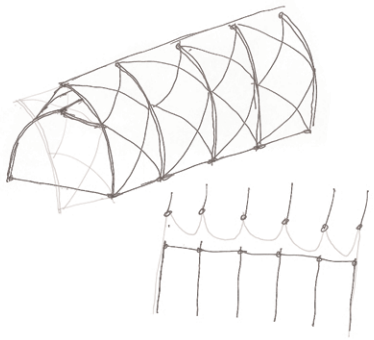

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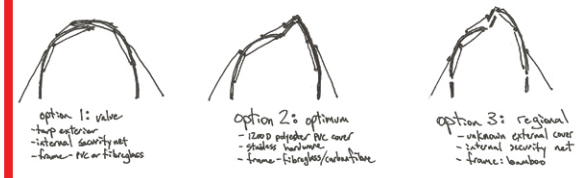


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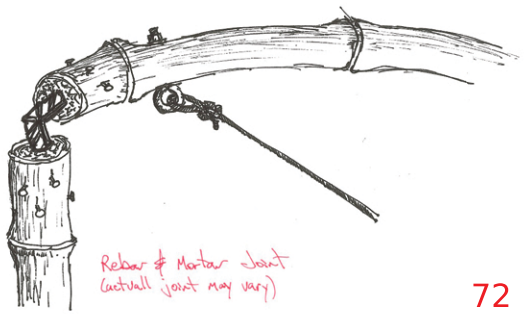


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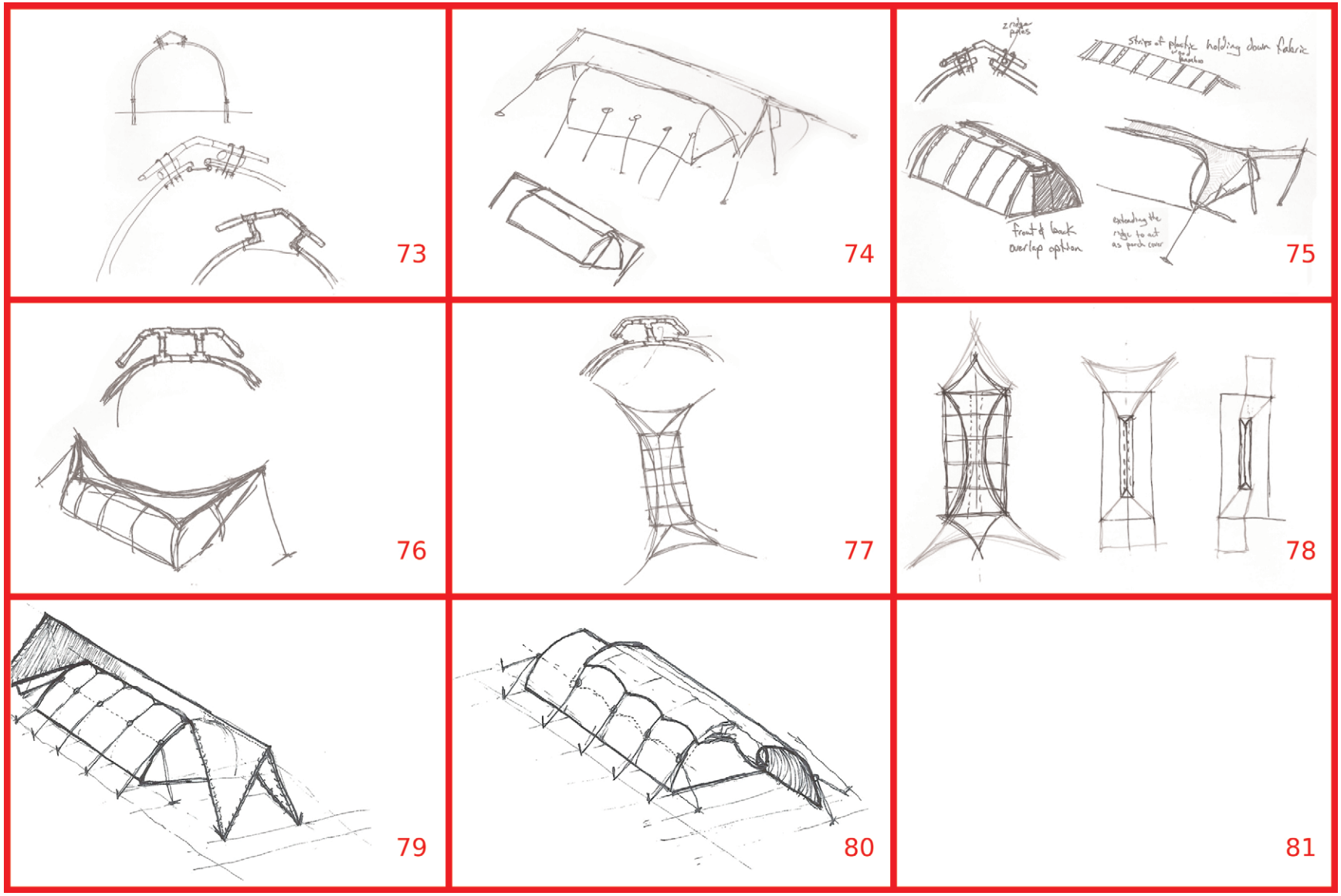
73
74
zipper pulls
straps of plastic holding down fabric
front & back overlap option
extending the right to act as porch cover
75
76
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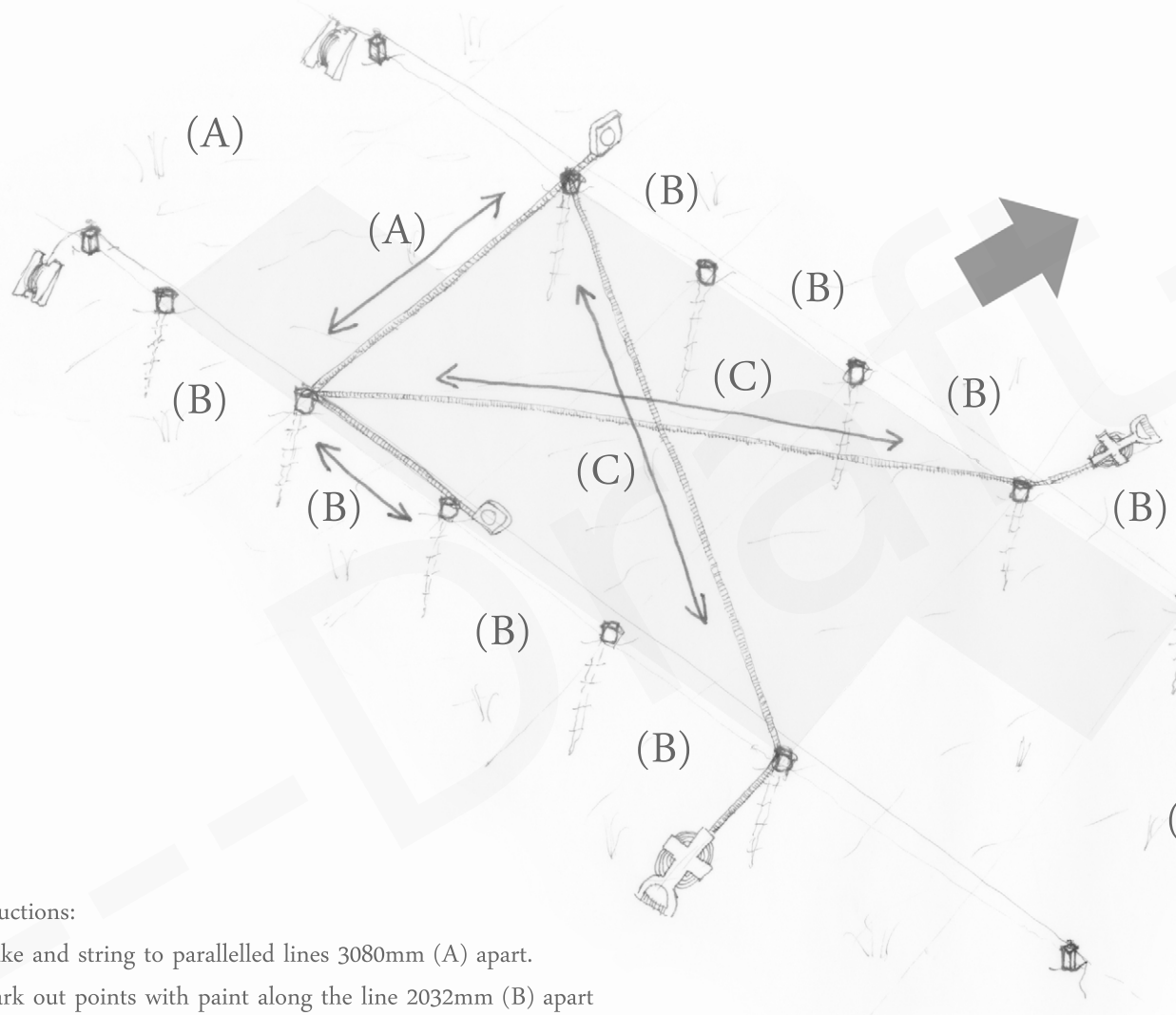
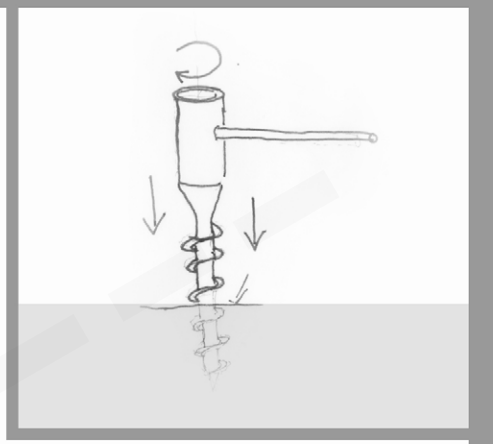
X09

# Instruction Guide (first draft)



4 Screw in galvanized ground screws until the the neck reaches the ground plane.

Instructions:

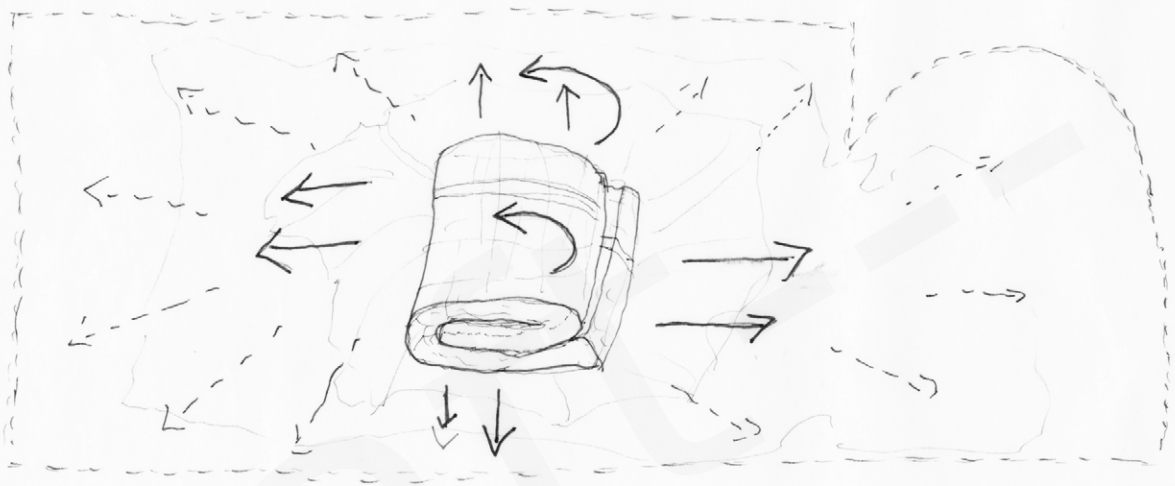
1 Stake and string to parallelled lines 3080mm (A) apart.

2 Mark out points with paint along the line 2032mm (B) apart with an interior core diagonal of 6833mm (C).

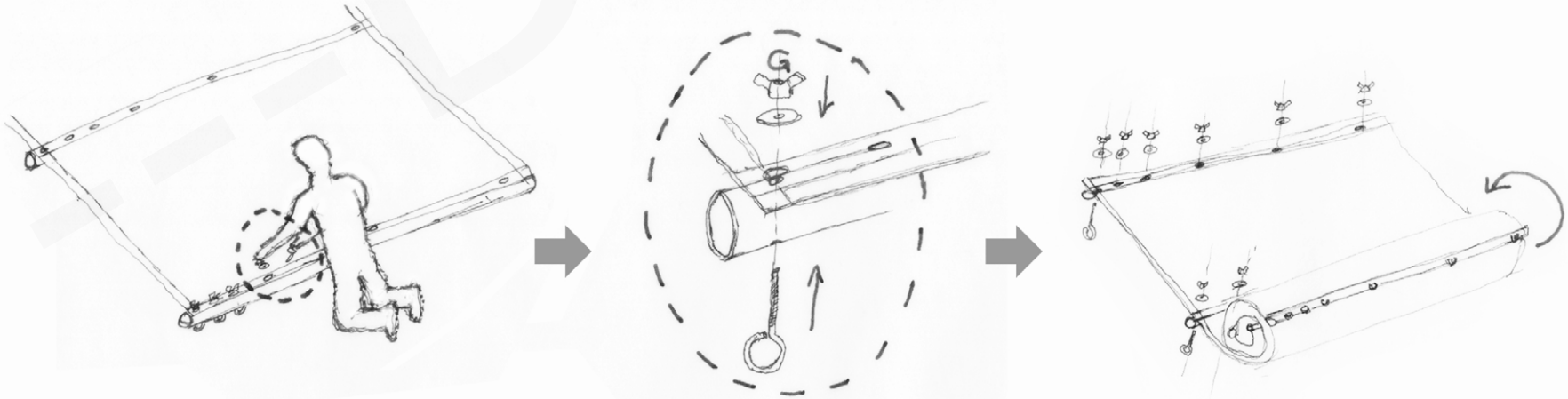
3 Before painting the final marks ensure the the core rectangle is square (C). Paint final marks for the ground screw team.

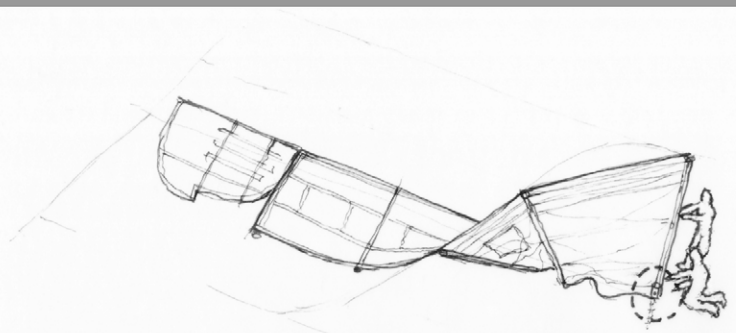
Images E56 - E65 (following pages)
The sketches presented in the first draft of the instructional booklet are to be followed as visual aid for the BWSTR working drawings. If there is a dimension conflict found, use the working drawing dimension and not the instruction guide dimension. Further steps, drawings, and information will be added as this booklet becomes more refined.

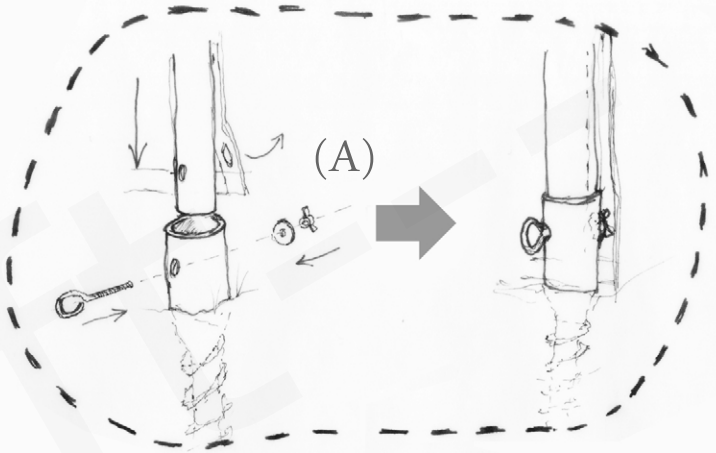
5 Find a flat area of land to unroll skin(s).
6 Take 25mm eyelet bolt and pass it through the frame holes on the frame side first.
7 Follow instructions labelled on tent skin to ensure that the skin faces the right direction.
8 Place appropriate fabric hole onto top of frame hole where eyelet bolt is coming through, place fabric hole over eyelet bolt until eyelet bolt comes through other side of skin.
9 Place 6mm washer onto eyelet bolt, thread 6mm wing-nut onto eyelet bolt until taunt.
10 Repeat steps 6-9 until eyelet bolts are in every frame hole.
11 Roll skin until you reach second area in skin for second frame piece, repeat steps 6-10 until all frame members attached to skin.
12 Repeat steps 6-11 on opposite skin side.

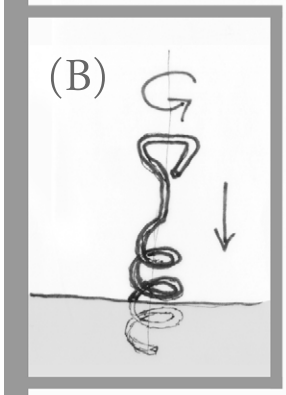


!!! Do not unroll skin onto sharp objects sucks as stones or hard debris !!!








13 Place frame and skin into corresponding ground screw.

14 Attach frame to ground screw with 25mm eyelet bolt (A), repeat this process for each ground screw.

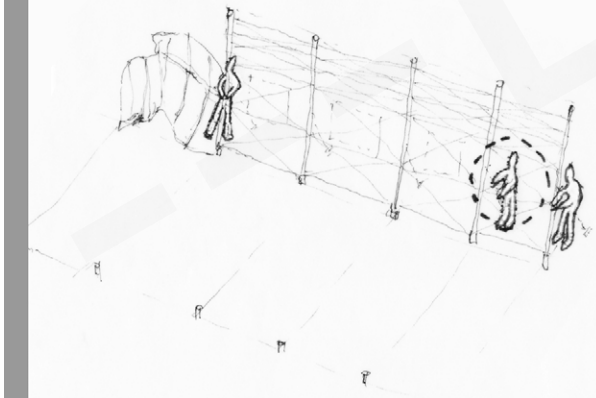
15 Repeat process for opposite side of shelter.

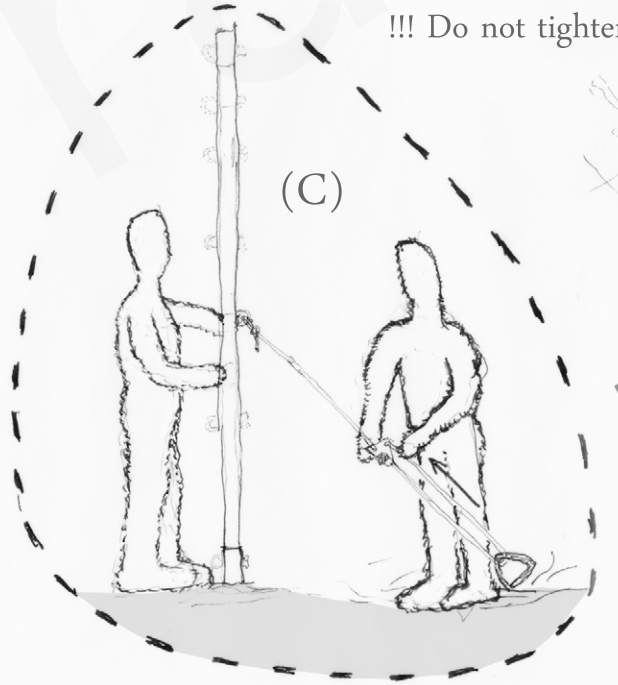
16 Screw in guy rope anchors (B) 940mm away from shelter in line with frame, place secondary guy rope anchor at each corner. Repeat process for opposite time.

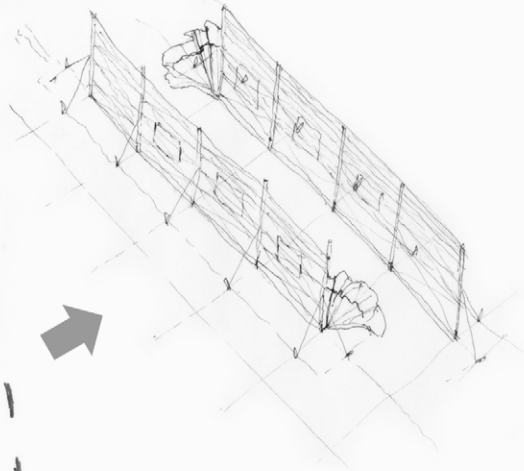
17 Attach guy rope supplied loosely (C) to the exterior eyelet that was assembled to the frame and skin.

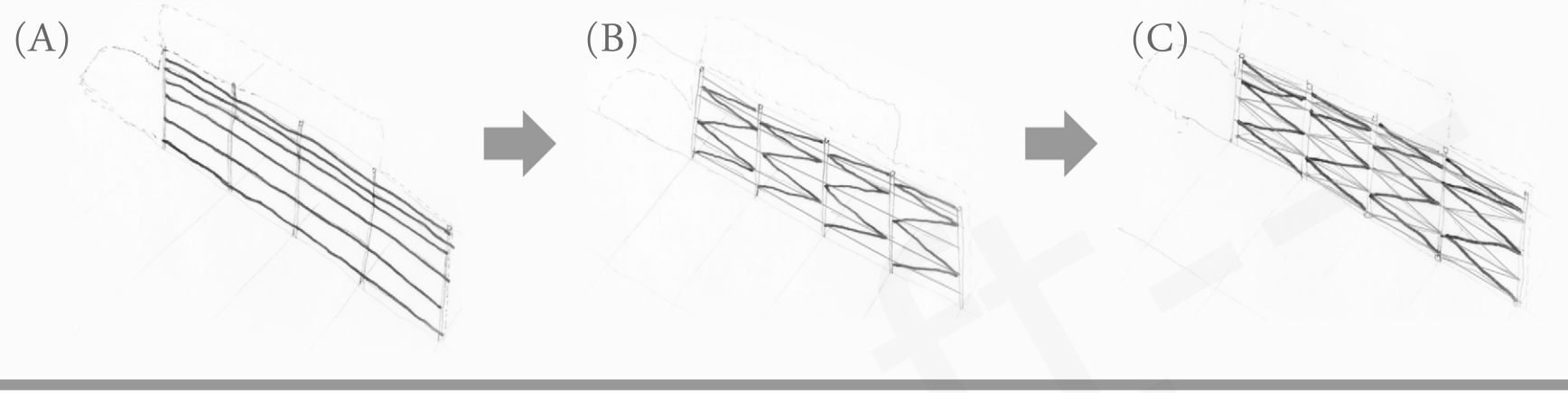
18 Refer to steps 25-29 on tying an anchor hitch knot and properly attaching tensioner to guy rope.

!!! Do not tighten guy rope until after step 40 !!!





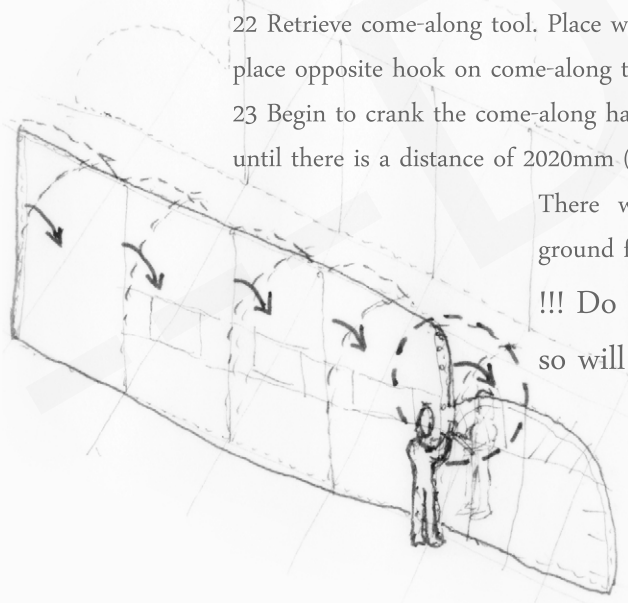






19 Tie rope provided on every eyelet of end frame member, thread through (A) corresponding eyelet on each frame. After threading through all eyelets, tie on opposite end frame member eyelets.

20 Starting at bottom eyelet of end frame member, tie nylon rope to eyelet and thread diagonally (B) upwards alternating eyelets as rope ascends through eyelets.

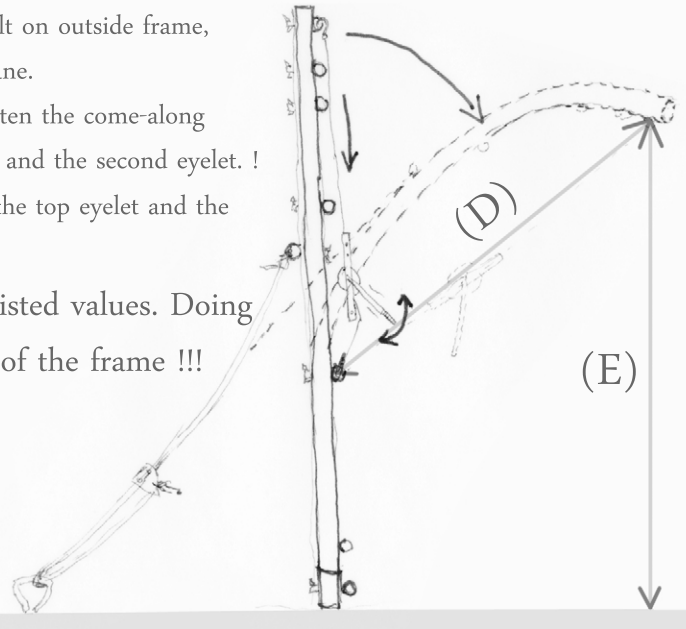
21 Repeat process, this time start at bottom of second frame member (C). Do the same for between frame members 2&3, 3&4, and lastly 4&5. Repeat steps 19-21 on opposite side of shelter.



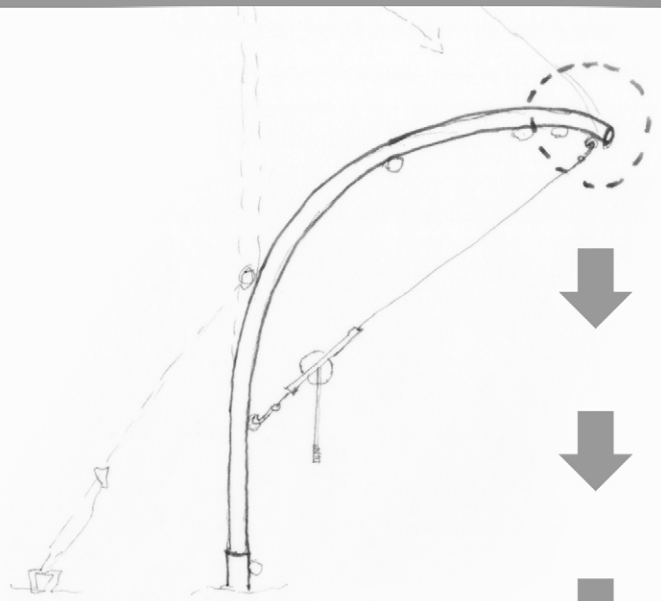
22 Retrieve come-along tool. Place wenching hook through the top eyelet bolt on outside frame, place opposite hook on come-along to the second eyelet from the ground plane.

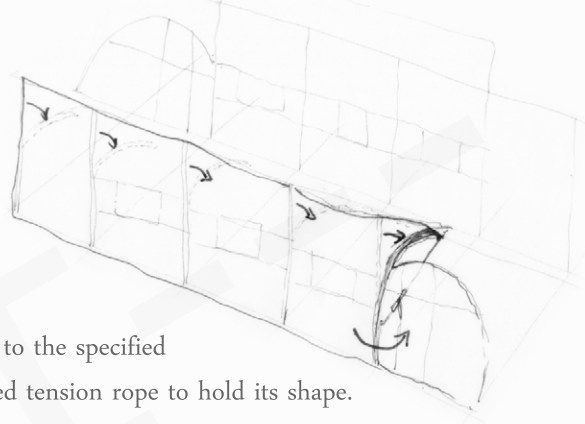
23 Begin to crank the come-along handle in a smooth constant manner, tighten the come-along until there is a distance of 2020mm (D) between the centre of the top eyelet and the second eyelet. ! There will be a distance between the centre of the top eyelet and the ground floor plain of 2100mm (E).

!!! Do not wench come-along beyond listed values. Doing so will damage the structural integrity of the frame !!!



!!! Repeat process for each frame member on both sides !!!





24 After the come-along has bent the pipe to the specified measurements, you must attach the supplied tension rope to hold its shape.
Tie the nylon rope to the top eyelet using an anchor hitch.

25 Tying anchor hitch: pass the tail twice (A) around the eyelet keeping the second turn slack. Pass the tail over the standing end (B) and under the original slack. Continue around the standing a second time (C) to complete the knot.

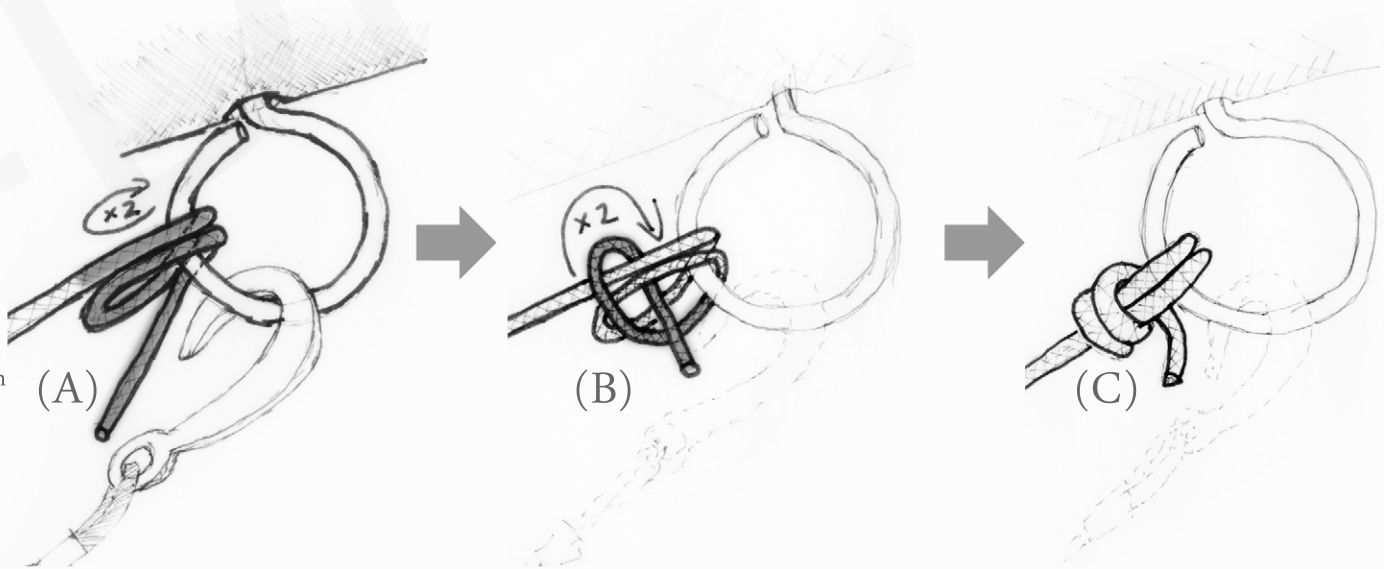
26 After knot has been tightened, thread the rope through eyelets along frame. Do not thread it through the second eyelet from the ground plane.

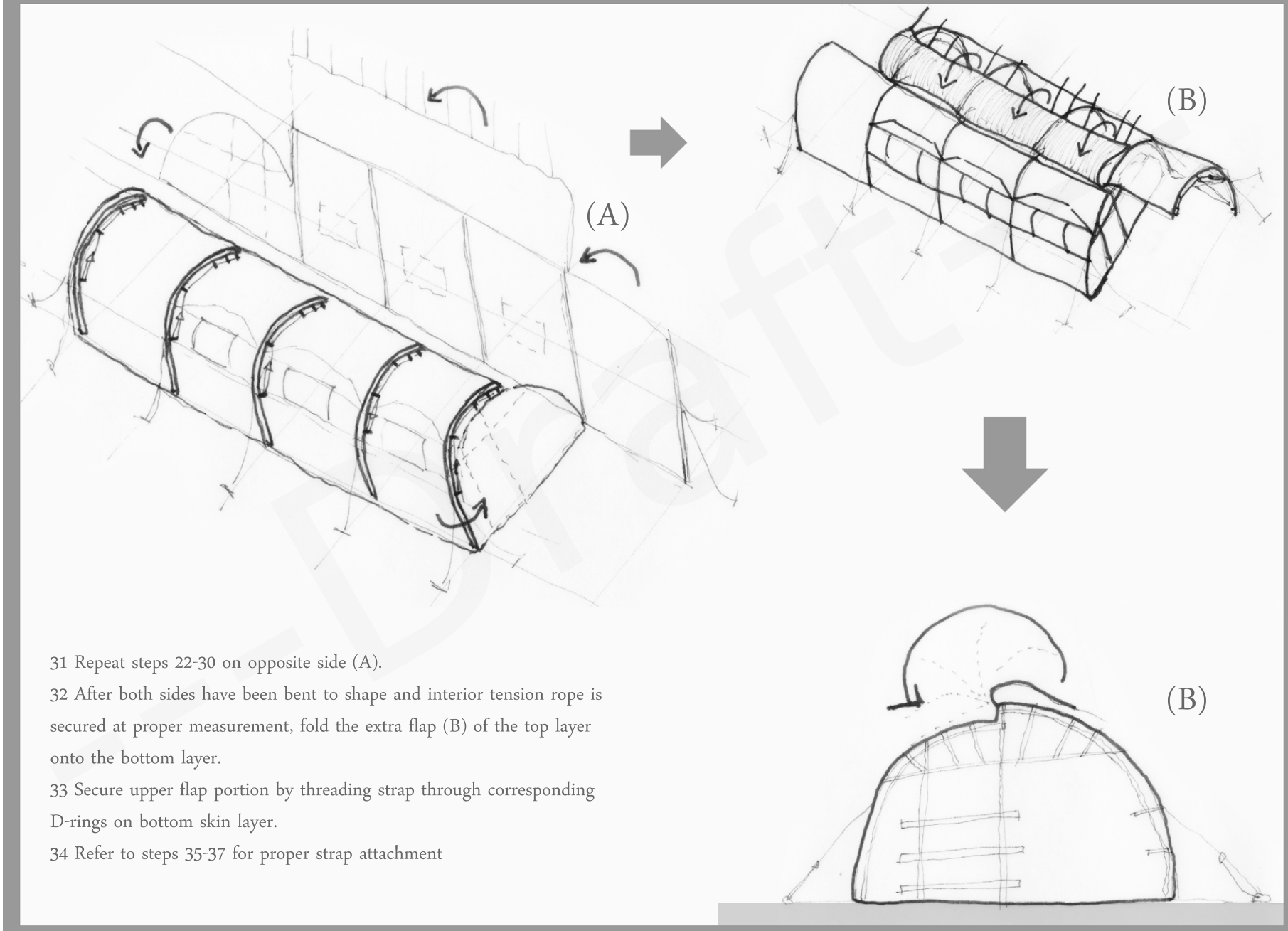
27 Before threading the rope through the eyelet, thread rope through one half of the supplied guy rope tensioner.

28 Thread rope through second eyelet from ground plane.

29 Thread rope through second half of guy rope tensioner and finish the thread process with a square knot.

30 The interior guy rope should measure a total of 2240mm from eyelet to eyelet while in tension. The upper skin will measure 2225mm while in tension.





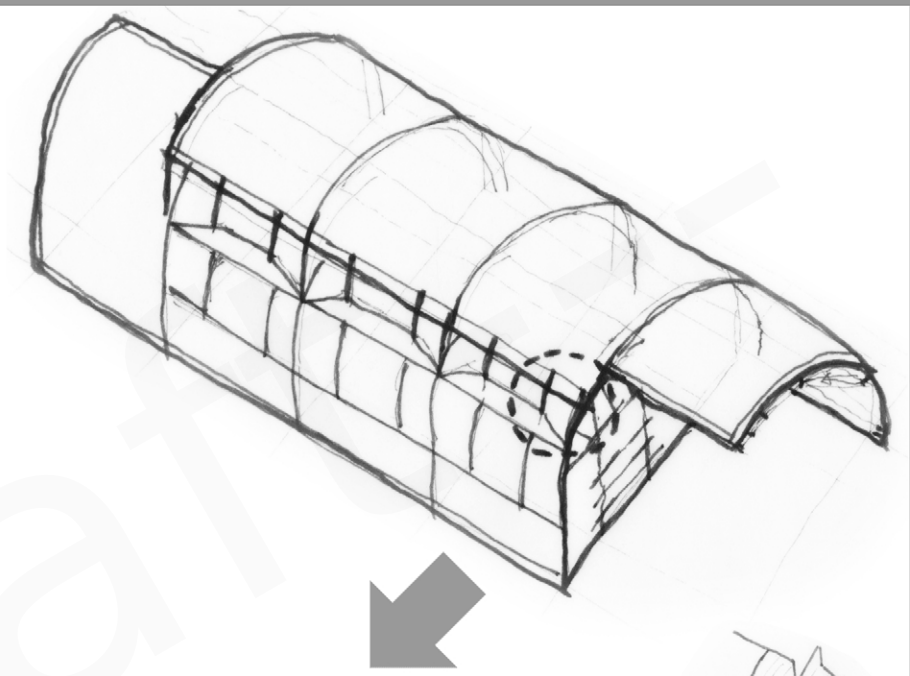

31 Repeat steps 22-30 on opposite side (A).

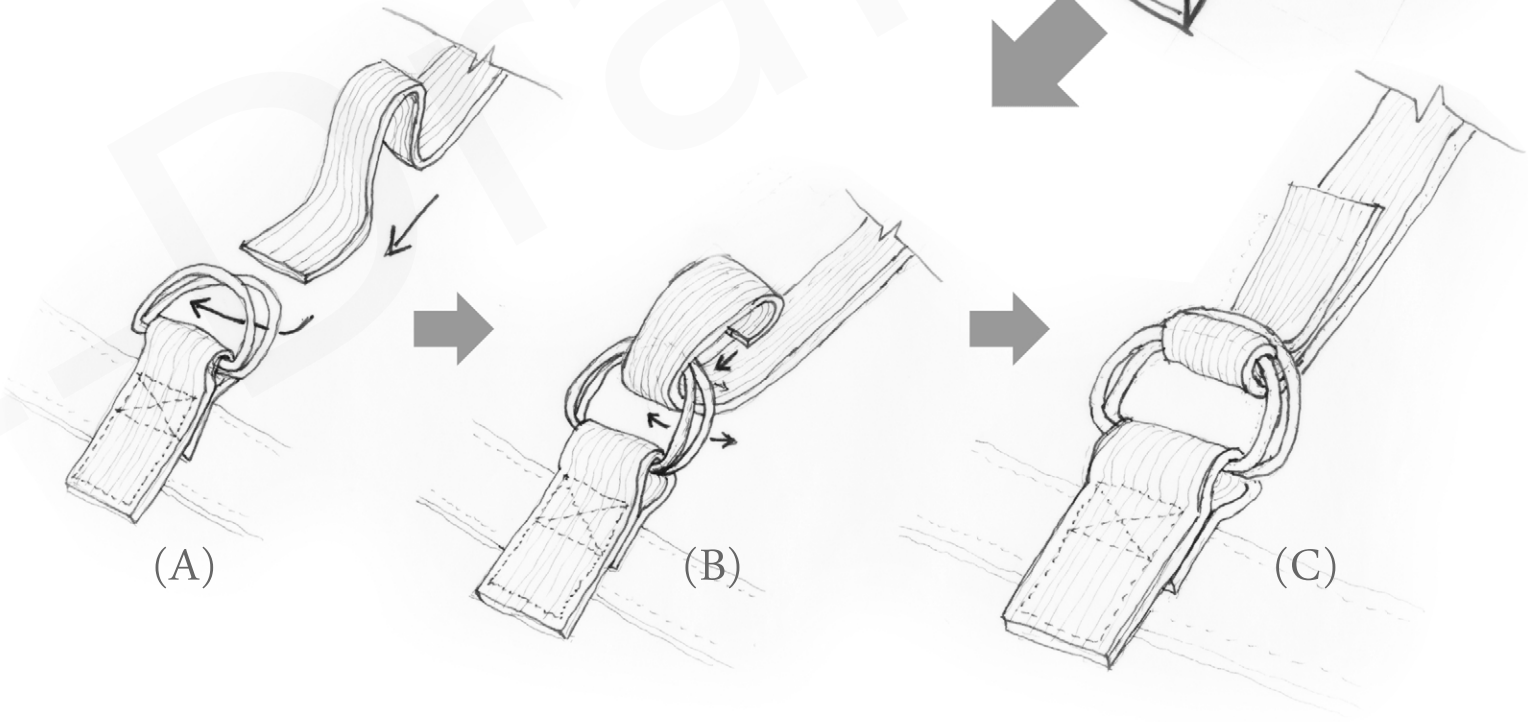
32 After both sides have been bent to shape and interior tension rope is secured at proper measurement, fold the extra flap (B) of the top layer onto the bottom layer.

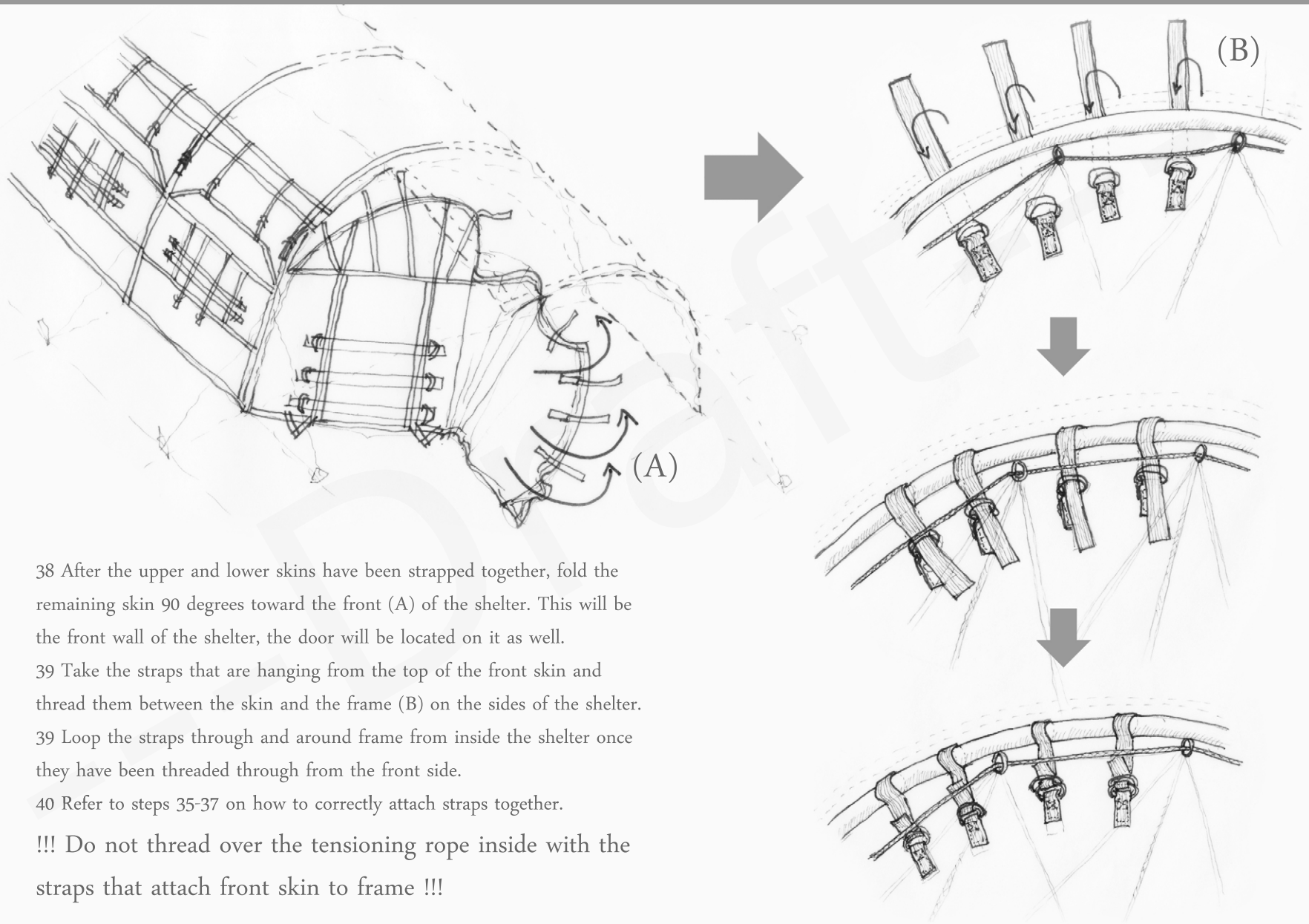
33 Secure upper flap portion by threading strap through corresponding D-rings on bottom skin layer.

34 Refer to steps 35-37 for proper strap attachment

35 Attach upper and lower skins using straps fixed to skin by threading the upper skin strap through (A) both bottom D-rings.
36 Next, thread the strap over the last D-ring continue to thread strap (B) between each D-ring.
37 Lastly, after strap has been treaded between the D-rings, continue to thread strap through the last D-ring (C) and pull strap until taunt. If done properly the strap should meet back with itself and not come apart when upper and bottom skins are pulled away from each other.







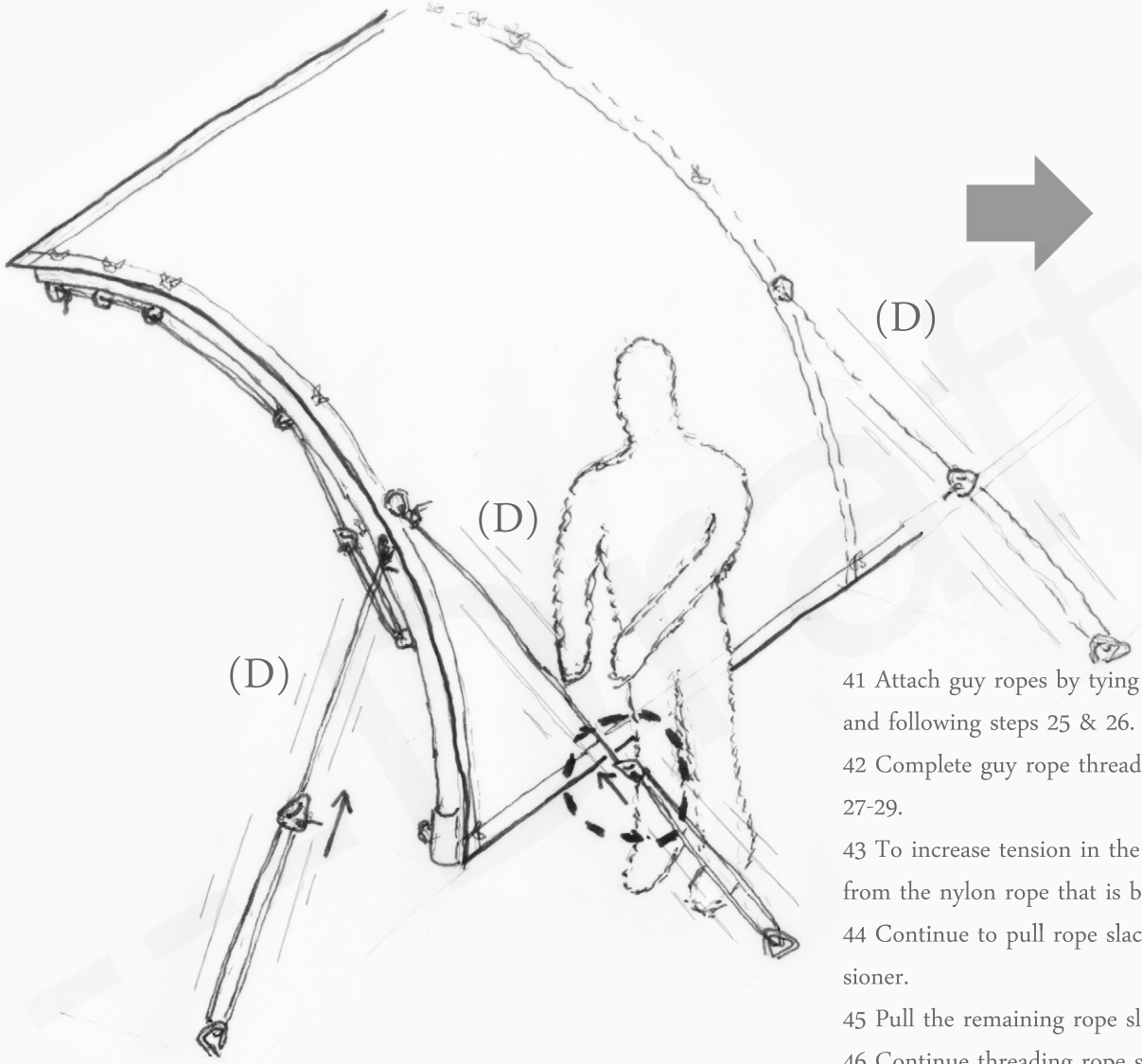

38 After the upper and lower skins have been strapped together, fold the remaining skin 90 degrees toward the front (A) of the shelter. This will be the front wall of the shelter, the door will be located on it as well.

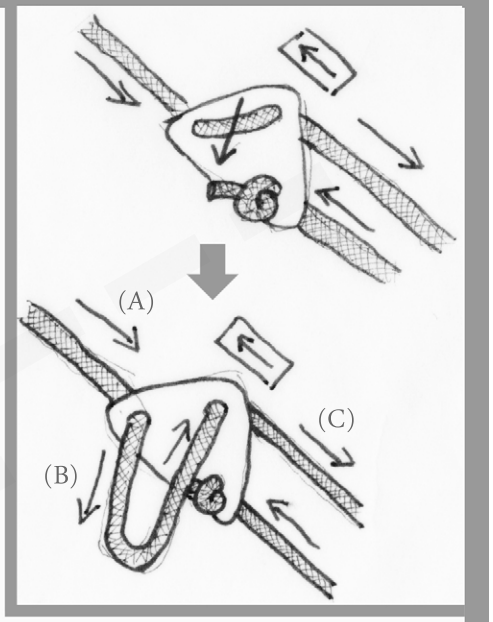
39 Take the straps that are hanging from the top of the front skin and thread them between the skin and the frame (B) on the sides of the shelter.

39 Loop the straps through and around frame from inside the shelter once they have been threaded through from the front side.

40 Refer to steps 35-37 on how to correctly attach straps together.

!!! Do not thread over the tensioning rope inside with the straps that attach front skin to frame !!!




!!! Do not over tighten guy ropes. Over tightened guy ropes will snap or damage the tent in high winds !!!

41 Attach guy ropes by tying anchor hitch knot using nylon rope supplied and following steps 25 & 26.

42 Complete guy rope threading and tensioning process by following steps 27-29.

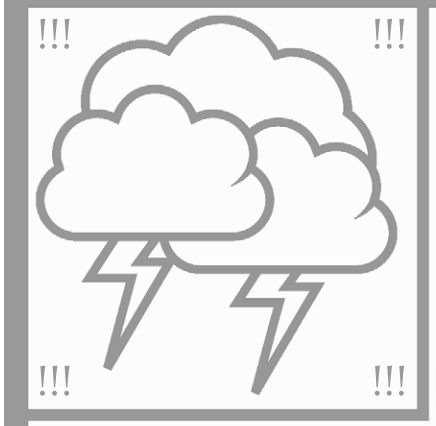
43 To increase tension in the guy rope using the tensioner, simply pull slack from the nylon rope that is between tent eyelet and guy rope tensioner (A).

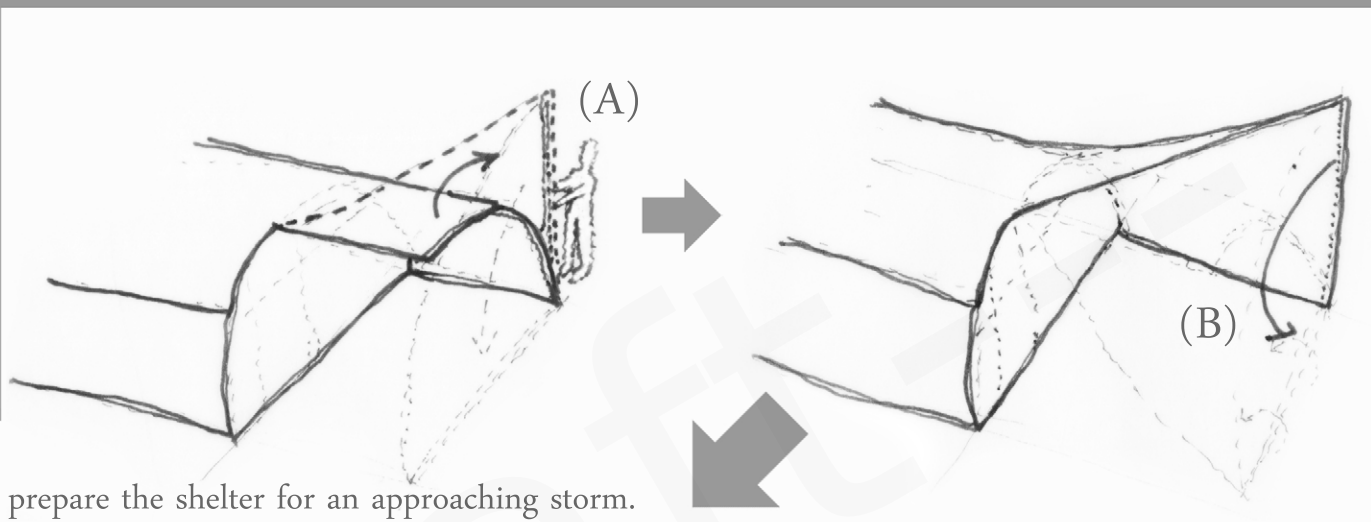
44 Continue to pull rope slack through looped (B) area of guy rope tensioner.

45 Pull the remaining rope slack (C) through last hole of rope tensioner.

46 Continue threading rope slack through guy rope tensioner until guy rope becomes taunt (D). Do this for every guy rope supplied.

47 Double check every rope tensioner on the shelter, ensure that there is even amounts of tension and pressures being applied throughout the shelter.




Follow these instructions to prepare the shelter for an approaching storm.

S1 Unlaced the horizontal bracing ropes from step 19, tie the loose end to the second frame pole and ensure horizontal rope is taunt.

S2 Unlace bracing rope from steps 20 & 21 between frame poles 1&2.

S3 Detach interior frame tensioner and exterior guy rope on the exterior frame member that is exposed in the area of the covered porch (A).

S4 Remove hardware attaching frame member to ground screw (B) and place frame and skin on the ground.

S5 Using two people, roll up the skin (C) and frame together until the roll reaches the front wall skin.

S6 Stake the roll using long stakes and driving them on an inward direction facing the tent (D). This will ensure that the rolled fabric will not blow away in high winds.

S7 After the storm, assess shelter damage to determine if any repairs are needed. If so, contact the appropriate supplying organization. If not, reassemble outdoor covered living area.