POST-SIDR FAMILY SHELTER RECONSTRUCTION BANGLADESH

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Field-work carried out between February and June 2009.

Family made destitute by Cyclone Sidr.

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SUMMARY

The key messages in this report are for the benefit and guidance of future rural housing programmes in Bangladesh. They have been derived from the experiences of family shelter reconstruction in the wake of Cyclone Sidr. However these lessons should not be limited to reconstruction projects after floods or cyclones: they are equally relevant to developmental programmes that have preparedness and disaster risk reduction at their heart.

There is a strong emphasis on technical issues – on proficient design, robust engineering and good construction techniques. This emphasis is deliberate. It responds to a well-recognised gap in shelter provision: there is often scant attention given to structural engineering and sound building methods despite the obvious hazards from flooding and storms. This discussion of technical issues is however set within the context of good humanitarian practice.

It is not a manual. It includes key messages and pointers, but these must be accompanied by good construction detailing and engineering.

This report concentrates solely on the reconstruction efforts after the widespread destruction and suffering in southwest Bangladesh. Many of the principles expressed here will be of relevance to housing projects in other regions of Bangladesh. However, like all building projects, there are no “off the shelf” solutions. Each circumstance should be treated on its own merits – nothing should be directly copied.

Core shelters must be built to provide appropriate, safe and durable family homes in a manner that is easily understood and replicated. Achieving this will be a significant step in setting a higher standard for post-disaster reconstruction in Bangladesh.

The findings of this report are centred on the programme developed by UNDP with finance from DFID. Nine thousand one-room core houses were built in the first phase; the second phase that began one year later, was for a further eight and a half thousand. However the authors have drawn on the experiences of several national and international NGOs that have been involved in post-Sidr reconstruction.

We are very grateful to everyone who advised and guided us through this process and in particular to the help and support from UNDP and DFID.

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B INTRODUCTION AND BACKGROUND

B.1 Bangladesh and Cyclone Sidr.

B.1.1 Bangladesh is one of the most hazard prone areas of the world. It is also one of the poorest countries. Endemic poverty, the annual risk of flooding, population density, regular storms and cyclones, all combine to create an unsurpassed level of vulnerability. In 2007, more than 50% of Bangladeshi territory was affected by severe seasonal flooding. Later that year, on 15 November 2007, Cyclone Sidr hit the southwest coast causing widespread destruction – the most severe and destructive cyclone for 15 years.[1] In late May 2009, yet another storm, tropical cyclone Aila, also struck the southwest breaching embankments at several points and 750,000 people have been made homeless by the ensuing flooding.[2]

B.1.2 Many lives were saved from Cyclone Sidr through early warning systems, cyclone shelters and evacuation, the product of previous years of preparation. Three million people were evacuated from the lowest lying areas. Nonetheless 4,000 people were killed. In stark contrast, it can be noted that 500,000 people lost their lives in a similar cyclone that struck Bangladesh in 1970.

B.1.3 However the lives of approximately eight and a half million people were affected by Sidr and one and a half million homes were partially or entirely destroyed.[3] 565,000 homes were completely destroyed beyond repair.[4]

Number of houses fully destroyed	565,000	
Number of houses built by agencies by end of 2008[5]	40,000	Approx 7%
Number of houses self built, assuming 66% self-recovery	373,000	
Number of families without adequate shelter early 2009	152,000	

B.1.4 Exact figures are elusive. The numbers in the table above are only intended to give an indication of the scale of the problem.[6] But it can be

1 See map of areas affected by Cyclone Sidr p10.
2 The number of Aila victims comes from an Oxfam International briefing note.
3 Figures from Oxfam briefing note , November 2008.
4 Comprehensive Disaster Management Programme, UNDP.
5 The Shelter Working Group report of 5 November 2008 mentions a target figure of 78,599 homes to be built, of which 30,411 had been completed.
6 These figures, with some adaptation and rounding, come from the UNDP Cyclone Sidr Family Shelter programme.

seen that of the total number of houses destroyed, under 10% had been rebuilt by humanitarian agencies, NGOs and other actors one year after the disaster. Even assuming a 66% self recovery rate, at the time of writing there are still 152,000 families facing a second monsoon without adequate shelter. These figures do not include partially damaged homes that have been repaired, nor immediate emergency shelter assistance (plastic sheeting, tents and so on) that was distributed in the immediate aftermath of the cyclone.

A core family shelter – UNDP phase I (all photos are by the authors unless stated otherwise)

B.2 Brief description of assignment and scope of report

B.2.1 UNDP, with DFID funding, built over 9,000 family shelters by the end of 2008. A second phase of the programme is now underway (June 2009) also partially financed by DFID funds.

B.2.2 Two independent consultants were engaged to assess quality and value of the first phase and to make suggestions and recommendations for improving the standard of the design for the second phase. The learning outcomes are presented in this report and it is intended that it should be of value in preparing for, and responding to, future disasters.

B.2.3 The consultants visited Bangladesh on three separate occasions. Their second visit included a half-day workshop in Dhaka. Seven different agencies made presentations of their shelter programmes and there was an open and honest discussion of the pros and cons, the successes and the lessons learned.[7]

B.2.4 The discussion in this report is limited to the reconstruction of completely destroyed family homes. The vast majority of the shelter models built by agencies as part of the reconstruction response fall into the category of “core” or “transitional” shelter (see definitions below).

B.2.5 The emphasis in this report is on engineering, construction, value for money and appropriate shelter practice. These are discussed, however, always within the context of more qualitative issues such as cultural acceptance, beneficiary reaction, participation, livelihoods, gender, environment and so on. The report concentrates on post-Sidr reconstruction in SW Bangladesh but the issues will have relevance for similar responses in other areas of Bangladesh.

B.3 Different types of shelter response

B.3.1 Shelter response broadly falls into four phases:

- preparedness before the disaster
- emergency response
- the recovery phase;
- permanent housing and settlement.[8]

B.3.2 These phases are not distinct. Materials distributed during the emergency phase (corrugated metal roofing sheets, for example) could be reused for the recovery phase. Houses built during the recovery phase intended, at

7 See Annex 2 to download presentations.
8 From *Shelter Projects 2008*, UNHABITAT

the time, to be temporary often become permanent. Improvements made in the safe construction of durable housing become an integral part of preparedness for any future disaster. The four phases overlap and are inter-linked.

> *Key message*
> Preparedness and disaster risk reduction (DRR) should always be an integral part of a strategic response.

B.3.3 The definition of family shelter also falls into four categories:

- emergency shelter – tents, plastic sheeting, shelter "kits"
- transitional shelter – intended to last only a short while until a more permanent solution is found
- core housing – often a single room, around which the family can extend, modify and improve. It provides the core to a permanent home.
- permanent housing.

B.3.4 The model adopted by the majority of agencies involved in the reconstruction of houses after Cyclone Sidr was the core house. This is a single room, sometimes with a veranda, built on a high plinth above the normal maximum flood line. The dimensions of the UNDP core house are 15ft x 10ft which translates to a metric floor area of 14 sq m. By Sphere standards[9], this provides the minimum recommended area for four people. Within this concept of the core house there is a wide variety of design, choice of material, cost and method of procurement (from owner built to contractor built).

Transitional housing Sri Lanka
Photo: Jo da Silva

Core shelter with veranda, Bangladesh

[9] Ref *Sphere Standards 2004*, p 219

C THE DEVELOPMENT OF A SHELTER PROGRAMME

C.1 Introduction

C.1.1 A shelter project has to respond:

- quickly – there are obvious humanitarian reasons, but also donor pressure
- well – the response will be judged by its quality
- appropriately – a shelter is much more than just a roof [10]

C.1.2 These three issues can conflict one with another. The pressure to respond quickly can result in rushed and inappropriate decisions. In the aftermath of Cyclone Sidr, with a monsoon due to begin within months and thousands of families living under plastic, there was clearly a humanitarian need for a timely response. However if the shelter is not designed to resist high winds, it will be destroyed in the next storm. If the solution does not consider, for instance, the needs of women and children or kitchen space or sanitation, then it will not be acceptable. The initial needs assessment will provide essential guidance through observation, key interviews and informal discussion with beneficiaries both men and women, community leadership structures and local and international NGOs. [11]

C.2 The design brief

C.2.1 An essential first step in the process is the development of a design brief – a statement of intent that will guide the design team. This will define the response (will it be core shelters? permanent housing?) and tailor it to the capacity of the implementing agency, the size of the budget and the needs of the beneficiary.

C.2.2 Several influences will help to define the design brief and the subsequent development of the shelter programme:

- Hazard analysis [C.3]
- Habitability [C.4]
- Appropriate shelter practice [C.5]

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[10] For a fuller discussion of these issues see Jo da Silva *Quality and Standards in Post Disaster Shelter*. http://www.istructe.org/thestructuralengineer/Abstract.asp?PID=7360

[11] For a discussion of Rapid Assessment Procedures (RAP) and Rapid Rural Assessment (RRA) see *"RAP and RRA techniques in emergencies" Slim and Mitchell* http://www.unu.edu/unupress/food2/UIN08E/uin08e0r.htm

- Durability – technical design of the core shelter [D]

C.2.3 This section examines some of the most important considerations that will influence this process.

> *Key message*
> Responding to the housing needs of families made destitute by a natural disaster is complex. It is important that the personnel and expertise are in place from the outset. Assessment and consultation are vital.

C.3 Hazard analysis

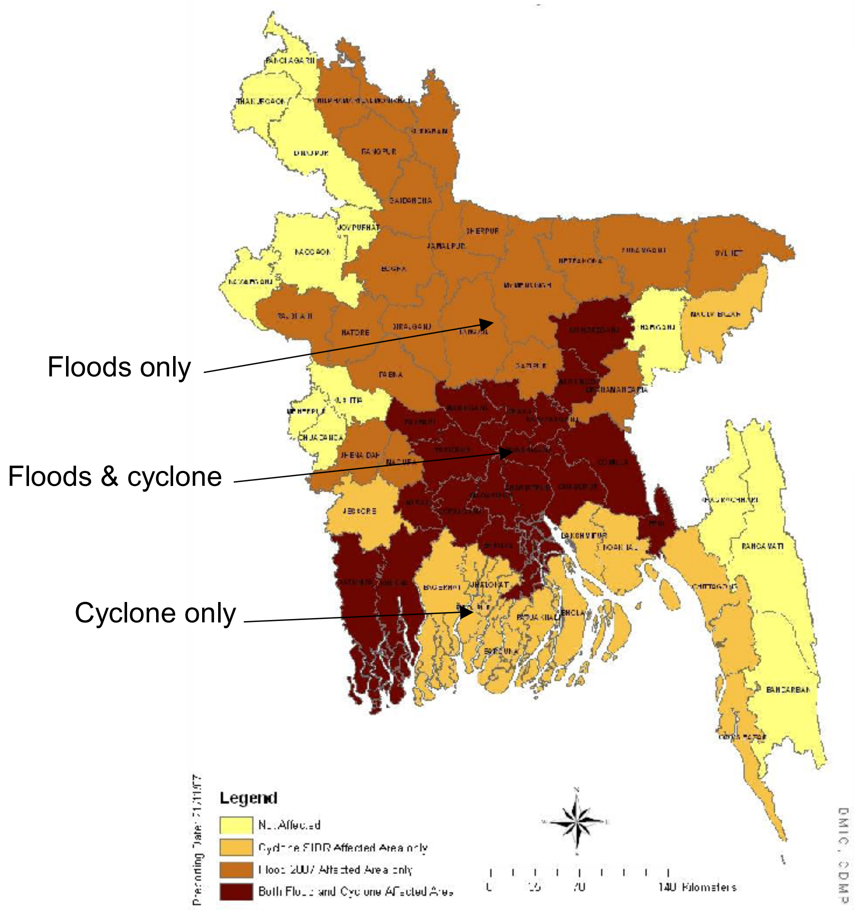
C.3.1 The risks associated with known hazards have to be considered dispassionately and not just in the light of the recent event.

C.3.2 After an earthquake, it is easy to assume that the major hazard is another earthquake; similarly after flooding, future flooding. In northern Bangladesh, there is much more likelihood of an earthquake than in the southwest which is seismically quiet. An informal survey in the area affected by Cyclone Sidr showed that people considered salinity and flooding to be more serious hazards than cyclones.[12]

C.3.3 An analysis of hazards will influence the design and cost of the structure. Frequently cost is quoted as a reason for not reaching a particular design standard: *"we cannot possibly afford to design for the wind strengths experience in cyclone Sidr"*; or *"there is no way that we can build a tsunami-proof house".* These assumptions should be questioned and justified. Houses must be built to withstand the kind of hazards that are experienced on a frequent basis; in SW Bangladesh, for example, this will probably be flooding and strong storms. Unfortunately, many of the post-Sidr houses were not designed to withstand commonly occurring storms and floods. (see diagram p27 of wind speeds and structure failure).

C.3.4 It is sometimes difficult to fully appreciate the scale of reconstruction after a disaster. In Bangladesh a cyclone or flooding can destroy hundreds of thousands of homes. Typical reconstruction programmes can run into thousands of units and cost millions of dollars. It is essential that a carefully considered design brief is written in consultation with all the stakeholders – and a hazard analysis will form an important part.

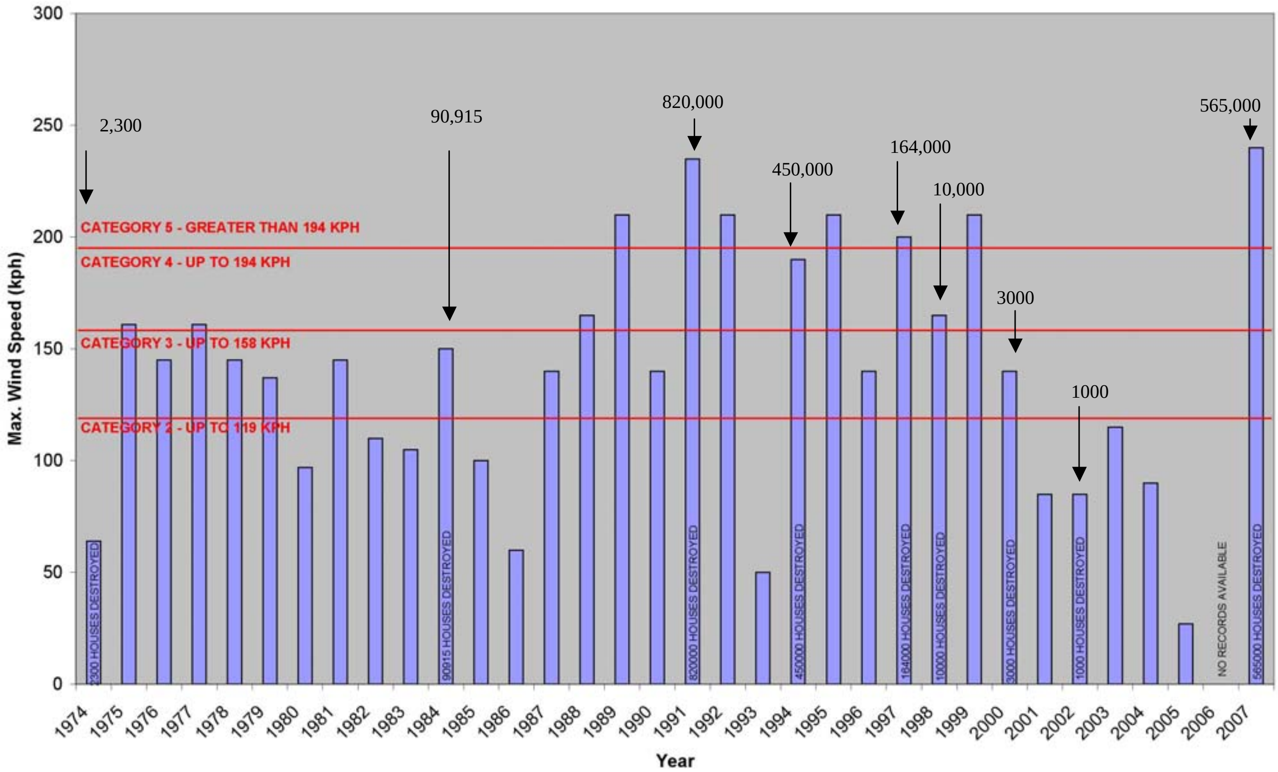
[12] Interview with CPDM, April 2009



Bangladesh 2007

Areas affected by floods and Cyclone Sidr

Source CPDM



The blue bars show the strongest storm for any given year; the numbers represent houses completely destroyed

Source CPDM / UNDP

C.4 Habitability[13]

C.4.1 An analysis of hazard is not the only factor in defining a shelter programme. It is equally important to ask the questions : is this design a good home? is it fit for purpose? is it habitable?

C.4.2 Here are some of the issues that must be considered:

- Privacy and dignity
- Temperature control and ventilation
- Protection from the elements – weatherproofing
- Can the structure be extended, is the plan flexible and adaptable?
- Sanitation and a clean water supply
- Livelihoods – is there space for a kitchen garden? somewhere for a sewing machine or to mend a fishing net?
- Security
- Cultural preferences and traditions
- Livestock – where do animals go during a cyclone?

C.4.3 The diagram below shows how all these issues need to be considered in order to arrive at a considered design. It is also clear that the priority given to each issue will vary from place to place – no two solutions will ever be the same.

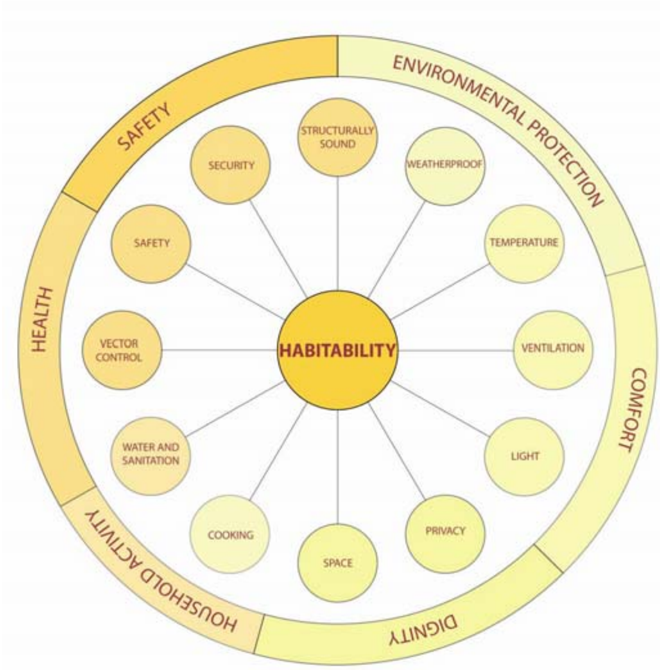


Diagram from "*Quality and standards in post-disaster shelter*" – Jo da Silva

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13 The concepts of habitability and durability have been considered in some depth by Jo da Silva in *Qualities and Standards in Post Disaster Shelter*. http://www.istructe.org/thestructuralengineer/Abstract.asp?PID=7360

C.5 Appropriate Shelter Practice

C.5.1 For a shelter programme to have an impact beyond the immediate beneficiaries, it is necessary to look beyond the issues of habitability, durability and an analysis of the likely hazards. Some of the concerns that the shelter team will have to address are discussed briefly below. These are by no means exhaustive and there are certain to be other equally important issues specific to the circumstances, the country and the capacities of the agency.

C.5.2 *Coverage, Cost and Scale*
As we have seen in the case of Cyclone Sidr, in most major disasters it is unlikely that more than a small percentage of the affected population will be the recipient of a new home. This raises questions about the appropriateness of certain kinds of design solutions. Put more simply: if all the houses in the community are destroyed but there is only the capacity to rebuild some of them, how does this affect thinking about an appropriate design? It is important that the design can be copied and that the technical improvements can be understood by the local builders. They are the ones who, inevitably, will help the remaining population rebuild their homes.

C.5.3 Is it better to build lots of cheaper houses, or less houses to a higher quality? There will often be a pressure to provide for as many beneficiaries as possible, fuelling a tendency to build to a lower quality. A judgement, in consultation with the community and other stakeholders, will have to be made to decide if it is best to cover all the needs of one community, or just the most vulnerable in several. There will be a drive to push up beneficiary numbers, even though it is known that only a small percentage can possibly be covered. However, houses built to withstand storm-force winds might become mini cyclone shelters serving several families. A more considered approach is likely to be of more lasting benefit in the long run.

C.5.4 Under desperate circumstances in an emergency phase, there is pressure to build cheap and fast. However in transitional or core house construction there is a strong argument for more robust structures built for fewer people.

C.5.5 *Skills, training, labour and the procurement method*
At an early stage it will be necessary to give consideration to the availability of skills and labour and the most appropriate procurement method (how the shelter project will be delivered; who actually builds the houses). Are the required skills available locally? If not, the skills may have to be brought in from elsewhere, but it may be better to reconsider

the appropriateness of the building method or think about training local craftsmen in improved building techniques.

C.5.6 These strategic decisions have an impact on the beneficiary in a number of ways:

- Livelihood opportunities may be provided through acquiring new skills
- Much needed cash will be injected into the local economy
- Conversely, using local labour may take people away from their normal sources of income – fishing or farming for instance
- A high level of care and quality may be ensured through a feeling of "ownership"

C.5.7 These early decisions will have a bearing on the choice of procurement method. There are several different models and each has its pros and cons.

- **Contractor model** – An outside contractor is wholly responsible for the construction. This has the advantage of simplicity and control and, in theory, it should provide an assurance of quality and price. However, as the contractor may come from some distance, it may not provide any training or livelihood benefits for the affected community. Nor does it help stimulate the local economy unless the contractor is encouraged to hire labour from within the community.
- **Community-led** – The necessary skills are found within the community. The project management and procurement of materials will often be done by the implementing NGO or a local project partner. This approach keeps the money within the affected community, but finding the required skills may not be easy and it is difficult to guarantee quality and cost planning. It may also take people away from their main source of income.
- **Assisted self-build** – The affected families are given materials and tools and possibly some training. This can be an efficient way of quickly providing rudimentary shelter but it is difficult to ensure quality and introduce technical improvements.
- **Cash, owner driven response (ODR)** – Nearly all houses in rural Bangladesh are built by the owner, the owner's family or local artisans. By the controlled release of tranches of cash, the owner is completely in control of the construction of their own homes. If this process is not accompanied by intensive training of local builders and sensitising of the community, there is no guarantee that improvements in building standards will be implemented. However the feeling of ownership is greatly enhanced and it is possible to avoid the "one size fits all" characteristic of large scale contractor-built shelter programmes.

Key message
The decision on procurement method affects the local economy, livelihoods, skills and training as well as the community sense of "ownership".

C.5.8 In most countries in the developing world, the majority of rural houses are built by the informal sector. They may not be self-built, but they will be constructed using labour and skills immediately available in the community. It is only after an event such as a cyclone that significant numbers of houses will be built by outside contractors engaged by INGOs, NGOs or other agencies. And as we have seen, only a small percentage of families have the good fortune to receive a new home.

C.5.9 The rest, the majority, will be built by the informal sector according to the resources of each family.

C.5.10 Ideally materials and techniques are chosen for the shelter project that are available and understood locally. This will encourage other self-builders to copy these improvements, particularly if they are simple and cheap. The training of carpenters and masons from the local community will also help ensure that the benefits will be widespread.

C.5.11 The quality of the workmanship of houses that were built post-Sidr by contractors was often to a low standard (see photo below). The quality of the construction carried out by the informal sector, paid for directly by the house-owner, was often much higher. Frequently the core house was of a low standard, but the verandas that were added on afterwards showed a much higher quality of workmanship.

Key message
An important consideration is this: how can the intervention of aid-agencies best help the majority of people who will, inevitably, have to rebuild using their own resources? Small improvements that can be copied are more likely to have a lasting impact than radical innovation.

Contractor built detailing to fairly low standard …

….by contrast, this veranda is built by informal sector to a higher standard of care and workmanship.

C.5.12 *Health and safety at work*

It is difficult to control health and safety on large-scale projects on multiple sites, but every effort must be made to ensure the well-being of the builders and neighbours. If a contractor is involved, they should be asked to produce a method statement or health and safety plan. A risk assessment should be carried out. Some simple measures that might be taken to reduce risk are:

- Offer tetanus vaccines to all workers
- Provide good footwear for everyone
- Provide gloves for people working with cement or lime or toxic timber treatments
- Avoid on-site welding and other dangerous power equipment
- Avoid the use of toxic materials
- Provide safe access for working at height
- Take particular care with deep excavations in unstable ground conditions
- Ensure that children are kept away from the site

> *Key message*
> The construction industry has a very bad record of work related injuries and fatalities. Every effort should be made to ensure a safe site

C.5.13 *Environmental impact*

It goes without saying that the environmental impact of a shelter project must be taken into account. It is self-evident that it is preferable to use materials that minimise waste, can be recycled and re-used and will cause no lasting damage to the environment.

C.5.14 In the reality, these sentiments are more easily stated than achieved. The urgency of the humanitarian response make it difficult to give due consideration to issues that, at the time, may seem secondary. However some common sense guidelines should be adhered to if possible:

- Avoid relying on imported products.
- Avoid excessive use of plastics
- Avoid using materials toxic to the occupant, the builder or the environment (for instance take care when choosing paint, timber treatment etc).
- Minimise materials that are polluting in their production (cement is a major pollutant – consider using a weaker mortar or lime).
- Avoid materials high in “embodied energy” (ie high energy use for extraction, production or transport).
- Ensure that timber is procured responsibly.[14] Consider planting trees as part of the programme but advice must be taken to ensure that appropriate wind-resilient trees are selected. Tall trees must not be planted too close to dwellings.

C.5.15 It is not difficult to come to the conclusion that all materials are on the prohibited list! Clearly judgements and compromises have to be made. It is also worth remembering that rural Bangladeshis are responsible for a minute proportion of the planet’s pollution but are repeatedly victim of the effects of climate change and deforestation completely beyond their control. Observers from richer countries should be cautious in the manner in which they approach this subject lest they be invited to put their own house in order.

Brick factory SW Bangladesh

C.5.16 Fired brick is a very common building material in SW Bangladesh, and this might serve as an example of how difficult it can be to reach a researched conclusion. It is an excellent product: strong, long-lasting, cheap, locally available and there are masons in many villages. On the other hand, the hundreds of brick factory chimneys around the city of Dhaka pollute the

[14] Ref: forthcoming publication: *Timber as a construction material in humanitarian operation.* IFRC, UN/OCHA, CARE International UK.

skies and huge quantities of firewood and coal are consumed by the fires that are kept continuously burning.

C.5.17 It is possible to carry out a Life Cycle Analysis to assess the environmental impact of a product or a process. However this is almost inevitably beyond the scope of a humanitarian programme.

> *Key message*
> Environmental considerations are a "cross cutting" issue that cannot be ignored. Where detailed information is difficult to obtain common sense should prevail.

C.5.18 Further discussion and extensive references on environmental impact can be found on the ProAct Network website – *http://proactnetwork.org.*

C.5.19 *Innovation and improved building techniques*
No-one denies that innovation and safer building techniques are valuable. However for improvements to have a widespread beneficial effect, they must be based on simple, incremental, easily replicable ideas that are founded in the traditional local building techniques.

C.5.20 Innovative projects often fit more comfortably in a developmental programme rather than a humanitarian one. There they can have a role in exploring better construction techniques that can be an important part of a disaster risk reduction (DRR) strategy. A good example might be the introduction of compressed cement/earth bricks that have been introduced successfully in many countries. The British Business group built 164 houses in Majher Chor as part of the post-Sidr reconstruction effort. These were built using compressed earth blocks and ferro-cement roof sheets. Each house included rainwater harvesting and a latrine.[15]

Majher Chor. Photo British Business Group

[15] Majher Chor. Architects Mukta Dinwiddie MacLaren and Engineers Highpoint Rendel and WSP.

C.5.21 *Following rules of thumb for un-engineered structures*
There are many manuals and guidelines for un-engineered structures. These provide very useful “rules of thumb” for the construction of one-off structures that may not merit the involvement of a structural engineer. However shelter projects are rarely, if ever, one-offs. Whenever there are multiple units, good design and technical input is essential to ensure quality. This is particularly important in areas of high vulnerability and high hazard risk, such as Bangladesh.

> *Key message*
> The design of rural housing should NOT rely on “rules of thumb”.

C.5.22 *Water and sanitation*
Ideally, all shelter programmes should incorporate water and sanitation. This should be carried out in co-ordination with the WASH (water, sanitation and hygiene) sector.

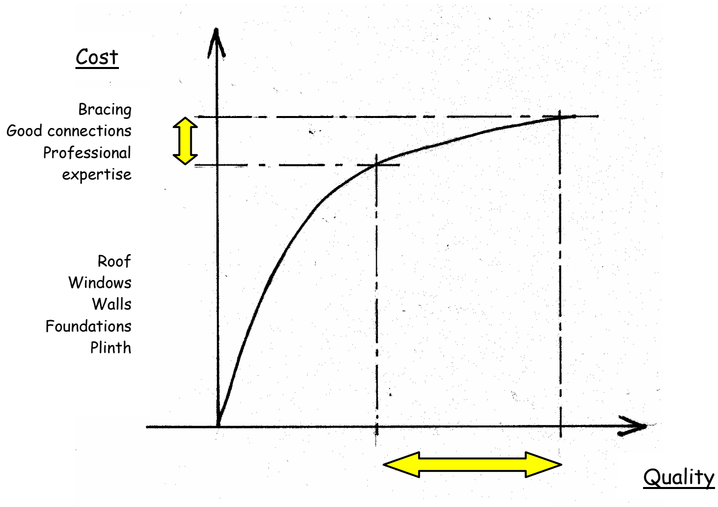
C.5.23 Access to clean, safe, non-saline water in SW Bangladesh is extremely uncertain. Most families rely on clay-lined ponds which are sometimes used for all domestic uses – washing, cooking and drinking. In some areas the water table has high levels of arsenic. Harvesting of rainwater is a very appropriate technology that goes hand-in-hand with the provision of family shelters. The selection of a site for the sealed water tank must consider the highest flood level. Such a tank, during flooding, can provide the only source of non-saline water. The family is likely to extend and adapt the core house and so the position of the tank must be made in consultation with the occupant.

C.5.24 Latrines must be sited several metres away from ponds and high enough to avoid being flooded.

> *Key message*
> Water and sanitation is a specialist area. Work must be done in consultation with WASH sector engineers.

C.5.25 *Cost against quality – reducing long-term vulnerability*
A small increase in the total cost of a core house can result in a large increase in quality. An example probably best illustrates what is meant. All houses have foundations, walls, windows, a roof. This represents most of the cost – let’s say 90%. If the remaining 10% is spent on cross bracing, proper strong connections and J-hooks to hold the roof down, then a very significant increase in value, quality and safety will have been achieved for a small increase in cost. This is illustrated by the graph.

C.5.26 When hundreds, and sometimes thousands, of units are being constructed, this is an important factor to be considered. An increase in the unit cost will mean less shelters built overall, but the standard will be higher. The small increase in cost that significantly improves quality and safety can be seen as excellent value for money.



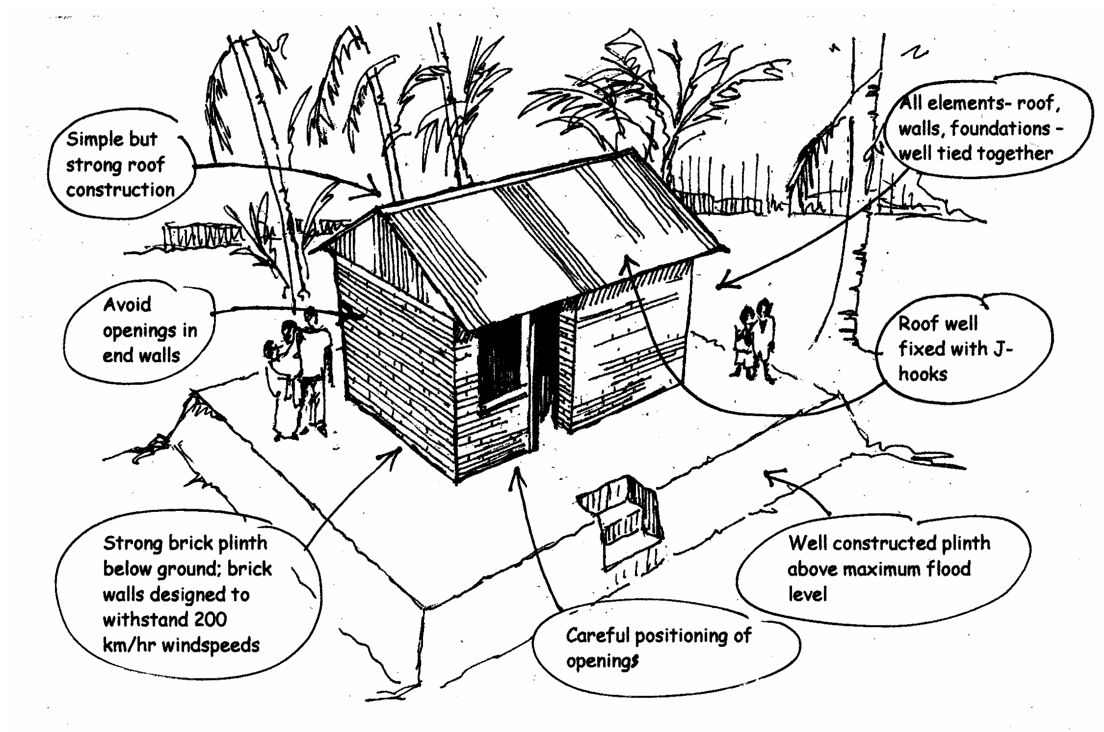
A small increase in cost can result in a substantial increase in quality

C.5.27 This argument not only applies to cost. A small increase in staffing levels, for instance, can also produce a significant increase in quality. Similarly an increase in technical expertise at the outset of the project design process can produce significantly safer, stronger buildings.

C.5.28 Another factor that obeys this general rule is time. There is always a time pressure. It can come from donors, government or agencies as well as an obvious humanitarian urgency. A small increase in the time spent preparing a proper, well-designed, well-considered response will be time well invested.

> *Key message*
> A small increase in cost / expertise / time can result in a considerable increase in quality that will reduce long-term vulnerability and protect livelihoods.

D TECHNICAL DESIGN OF CORE SHELTER



D.1 Structural Engineering

> *Key message*
> We *strongly* recommend that all partners carrying out any form of shelter design employ an appropriately experienced and qualified Structural Engineer to assess the most relevant hazards and forces, and to calculate and detail the structure to realistically meet the needs of the beneficiaries.

D.1.1 In addition, the Engineer must be pressed to *creatively* consider the structural options available, for cost assessment by the procurement team, so that the best possible structure can be achieved within the available funds. It is not adequate for the Engineer to simply certify the design proposals made by others on the basis of previous experience, which might not be exactly the same as the project in hand.

D.2 Hazards

D.2.1 The principal structural hazards and forces that must be considered in rural southwest Bangladesh include:

- Flood and tidal surge undermining and destroying houses
- Cyclone wind speeds destroying cladding, roofs and complete structures
- Salinity in water and air
- Termite attack

D.2.2 But even within the region, from village to village, priorities can vary (for more on "hazard analysis" see B.2).

D.3 Traditional house construction in rural southwest Bangladesh.

D.3.1 The majority of rural houses in the region are self-built by the owners, who expect to maintain and repair their homes seasonally.

D.3.2 Most self-build homes are small mud, timber or bamboo structures (or a combination of these materials), nailed or tied together and built on plinths made from compacted clay. It is unusual for a perimeter brick wall to be constructed around the plinth. Plinth height is based on experience of flood levels in each locality. Timber or bamboo posts are embedded into the plinth or rest directly onto it, on small timber or fired clay bearing plates, with timber beams forming a ring tie just above plinth level. Embedding the posts causes rapid decay of bamboo or timber, so they are often set in concrete or fixed to a separate stone or concrete base. The low level tie beam is often nominally anchored to the plinth with short nailed timbers embedded in the clay; these help prevent the house from being pushed off the plinth by water pressure or overturned by wind forces, and can be replaced when they decay. The clay

Rural house in Bangladesh

plinth is often no larger than the footprint of the house, but is frequently extended to provide greater flood protection. These plinths require regular maintenance by the family.

D.3.3 Wall coverings vary regionally but self-build rural houses are usually clad in timber boards, bamboo matting, galvanised metal sheet (CGI)[16], woven branches, thatch or compacted clay. Roofs are typically a hipped[17] timber framework, poorly fixed to the walls and clad in thatch, palm leaves or CGI.

D.3.4 The primary space (core) of the house is commonly extended with a simple mono-pitch veranda and side extension for the kitchen, on an extended plinth.

D.3.5 The houses have been constructed in this way because of the experience of many generations in fighting cyclones and flooding, doing the best they can with extremely limited resources. Generally however the roof timbers and fixings are too weak to resist cyclone winds. CGI sheets are sucked off the structure due to poor fixings, causing fatalities by the flying sheets. Plinths are easily eroded. Walls are blown over and whole houses are pulled from their plinths by wind and flood forces.

A well-built house destroyed by Cyclone Sidr

D.4 Shelter sector construction

D.4.1 In response to Cyclone Sidr, transitional and core shelter construction has generally copied the traditional poor family houses in size and layout, for both cultural and practical reasons. They have mostly been constructed on the restored original plinth. They are typically beam & post construction with simple hipped or gable roofs, and the most basic units are constructed in timber with CGI wall and roof cladding. Attempts have been made to improve stability, anchorage and durability, in order to extend life span and reduce maintenance.

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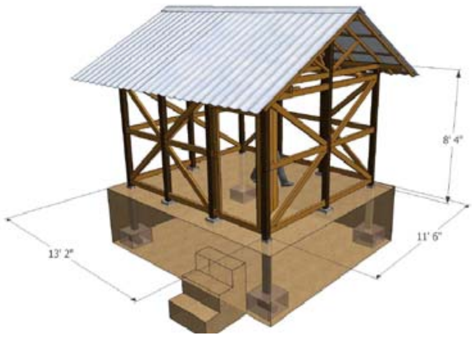
16 "Corrugated Galvanised Iron" roofing sheets, referred to in a number of different ways: corrugated roof sheets, "tin" roofing etc.

17 For illustration of the difference between a hipped and a gable roof see drawing on page 29

Key message
In spite of these efforts the shelter sector has often failed to produce the improvements that could be achieved. The opportunity to set good examples of simple construction, that other villagers could repeat, has frequently been missed.

D.4.2 Cross bracing between posts (and sometimes in roofs) with diagonal timbers or steel, and bolted connections, have been used to achieve greater stability. These are effective; although the timbers are frequently seen as non-essential and sold by the house owners, or taken down to make space for a window.



Timber-framed design - ACF

D.4.3 Where speed or economy was considered essential to meet transitional requirements, cross-braced timber posts have been used (see presentations by ACF and BRAC University[18]). But, for designers with higher budgets looking for more robust construction, reinforced concrete posts have become the most common construction form, combined with a hipped or gabled timber roof framework. These posts have some apparent advantages in terms of anchorage and stability, which have made them popular, and they have become accepted as the first choice for more permanent core houses in post disaster recovery phases.


Note the use of precast RC columns, woven bamboo matting and corrugated metal roofing sheets

Key message
However, in our view, pre-cast columns are a poor choice of construction, because of their low durability, high cost, limited strength, and quality control problems.

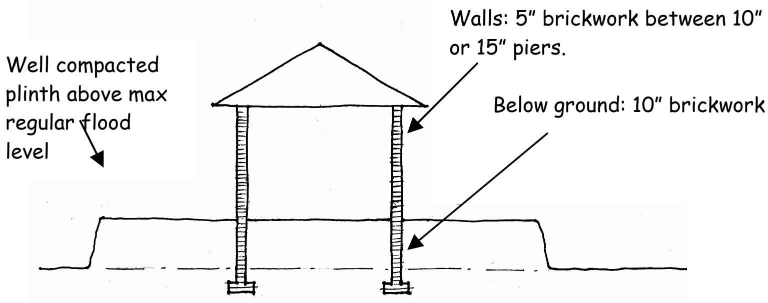
18 See Annex 2 to download presentations

D.5 Comments and Recommendations

D.5.1 *Foundations and plinths*

Brick plinths are undoubtedly the strongest base constructions for the region. They have the advantages of providing:

- Strong resistance to floods
- Weight distribution across soft ground to reduce settlement
- Anchorage against wind uplift and horizontal shear forces
- Protection to the house floor.



D.5.2 They reduce the need for maintenance and the owner can further protect them with additional compacted clay (usually for extensions to the core). Where they are left exposed the brickwork is frequently rendered by the owners to protect it against damp and insects. For the UNDP/DFID Phase Two core houses the plinth wall is continued up to form the walls of the house itself, creating a very robust unit with solid foundations.

D.5.3 Plinth brickwork should be 10 inches thick, or 5 inches with frequent piers. Ideally it should extend at least 18 inches below the original outside ground level, but local ground conditions must be considered. It is not necessary to widen the brickwork out to more than 15 inches at foundation level, unless the ground is very soft. Specifying wide foundations for average ground conditions is wasteful of brickwork and excavations.

> *Key message*
> Brick plinths/foundations offer the most practical robust foundation option in the region.

D.5.4 There are hundreds of brick factories in the region, but where cost and urgency don't allow a brick plinth construction, the clay plinth must be formed as robustly as possible. It should be well compacted, extending beyond the house (where the site allows it), and built to a height above flood level.

D.5.5 *Walls*

Timber or bamboo posts must be protected from damp as much as possible. They should ideally be fixed to an embedded anchorage point in the plinth. This can be a pre-cast or cast in-situ concrete base with a steel plate (see BRAC

University presentation[19]). Even these have only medium term durability but they provide something more robust, with greater anchorage than traditional methods.

> *Key message*
> Well-detailed traditional beam & post construction in timber or bamboo, with good use of cross-bracing, is an appropriate form of transitional construction, where cost and speed are critical. In this case, everything possible should be done to improve durability.

D.5.6 Pre-cast concrete posts can be fully embedded directly into the plinths, providing anchorage and some stability due their cantilever strength. But they rely on cross-bracing to achieve real storm resistance and they have limited durability in saline conditions, above and below ground. The posts are usually constructed using porous brick chippings for aggregate, often with saline water, and limited cover to the reinforcement. For reinforced concrete to have any chance of lasting more than 5 or 10 years in this environment it is essential to:


This is what happens to poor quality concrete in saline environment

- Use good materials - stone aggregate, sweet water etc.
- Provide enough Concrete cover to reinforcement - we suggest 35mm (not possible in small sections)
- Rigidly fix reinforcement, within accurate formwork, with good quality spacers etc, to maintain re-bar position during the pour
- Ensure good compaction during the pour with mechanical vibrators
- Insist on early, continuous and prolonged curing.

D.5.7 It is almost impossible to achieve all of these requirements in the region, even in a workshop. There are numerous other difficulties with pre-cast posts – for example when they are moved too early they can crack before they even reach the site.

D.5.8 When pre-cast posts are combined with lightweight cladding, timber rails are usually fixed to the posts with bolts or cast-in rebar, at levels to suit the cladding material. A similar detail is used for fixing cross-bracing. We saw several cases where the connections had been poorly carried out. This form of construction does not have sufficiently reliable stability to provide shelter in storm conditions.

[19] See Annex 2 to download presentations.

D.5.9 When reinforced posts are combined with brickwork panels, the posts are sometimes roughened at the faces (scabbled) for bond. However this does not achieve significant bonding and there is very limited combined action between the posts and brickwork. The posts essentially work alone and there is a danger of brickwork being blown in, under high wind pressures.

> *Key message*
> In our opinion reinforced concrete posts are not appropriate for transitional or core house construction in the region, although they have become very popular.

D.5.10 Brickwork used without pre-cast posts is the most robust form of wall construction and makes good use of local resources, with greater simplicity, and a cost saving when compared to pre-cast post / brick infill construction. Brick piers fully bonded to brick panels are actually stronger than pre-cast posts, and considerably more durable.

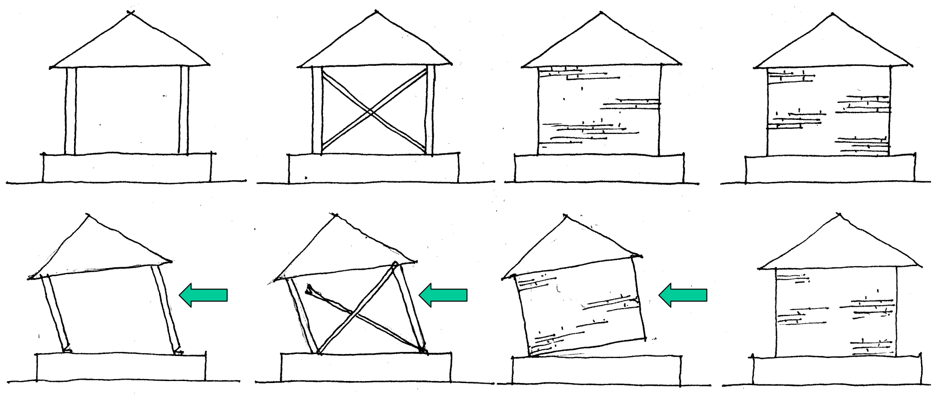
D.5.11 Mortar should not be too strong, as this creates a brittle structure, which cracks more easily. It is essential to use clean water for mortar. We recommend a sand: cement ratio of approx 1:5, and a water: cement ratio no greater than 0.6.

D.5.12 Wall opening positions for windows and doors must be carefully considered. Openings in the short end walls weaken the structure considerably. Ideally we recommend limiting openings to one front panel and one rear panel for maximum stability in cyclone prone areas. Allowing some airflow through the house will reduce wind-lift forces on the roof, so air holes should be left in brick walls.

> *Key message*
> For more permanent core housing, brick wall & pier construction is the strongest and most durable option. It is an understood and repeatable technique and provides homes that can act as mini storm shelters in areas where thare is no danger of very high tidal surge**.**

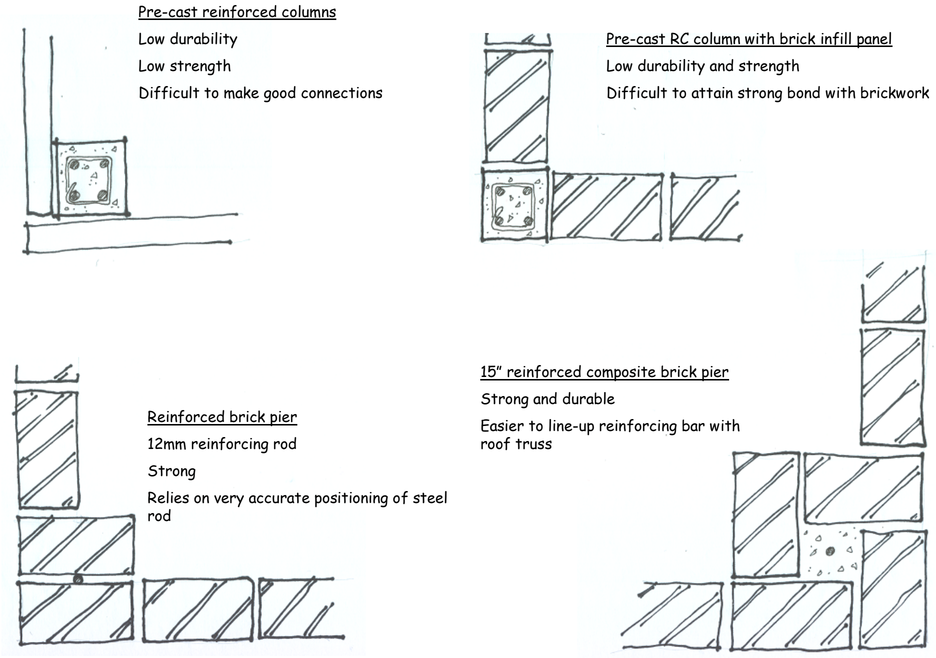
D.5.13 Further improvement can be achieved using brick pillars reinforced with a single re-bar and *in-situ* concrete. If it is combined with steel ties at roof level this achieves much better overall stability by framing the panels. The brickwork provides some protection to the concrete in-fill, and the single central bar is well protected by both brickwork and concrete. This detail should achieve a relatively strong and durable construction, even using crushed brick aggregate and lower quality site mix concrete. Care must be taken to pour the concrete in small sections and keep the void clean of mortar droppings. (See diagram p27 and drawings in Annex One)

Key message
Reinforced brick pier construction will achieve extremely strong and durable cyclone resistant shelters, when combined with a steel roof structure.



5" precast RC column	5" precast RC column with diagonal cross-bracing	10" brick column	15" composite column
58 km/hr	***100 km/hr***	***Category 3 158 km/h***	***Category 4+ 194++ km/hr***

This shows the design windspeeds at which different structures would fail



This shows different designs for columns and brick piers - plans

D.5.14 *Roofs*

The majority of traditional and shelter constructions we have inspected did not have a roof construction appropriate to resist strong storm forces. Timbers used for trusses, purlins and rafters were too small, with inadequate bracing to resist wind suction. CGI sheeting was poorly fixed. It is essential that roof structures are properly sized and detailed by a Structural Engineer.

D.5.15 A few implementing agencies have chosen to use steel roofs. These are undoubtedly far more resistant to cyclone wind forces. However it is essential to keep the steelwork detailing as simple as possible. The construction method and detailing must take into account the tolerances and accuracy that can be achieved at the site.

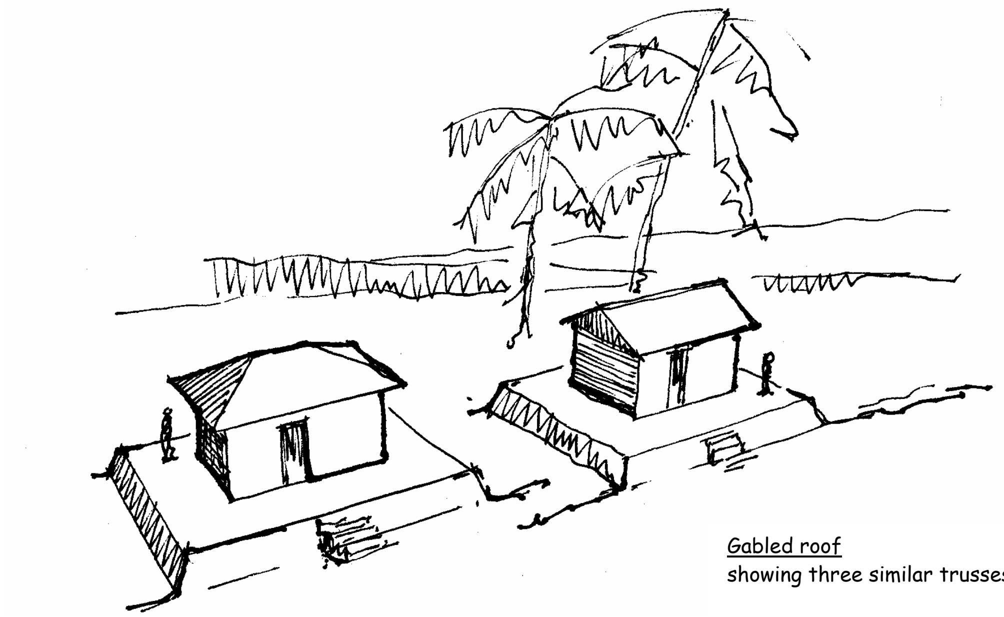
Steel roof truss - CARE

D.5.16 In theory, hip roofs should be stronger than gables[20]. However, gabled roofs are cheaper, provide more space, and can be fabricated more easily. In this case we have concluded that ease of construction also means a stronger roof. A gable roof can be made of three or four identical trusses.

> *Key message*
> A steel roof must be designed and FULLY detailed by a Structural Engineer, to ensure adequate strength, good use of materials, and to improve accuracy of fabrication in the workshop.

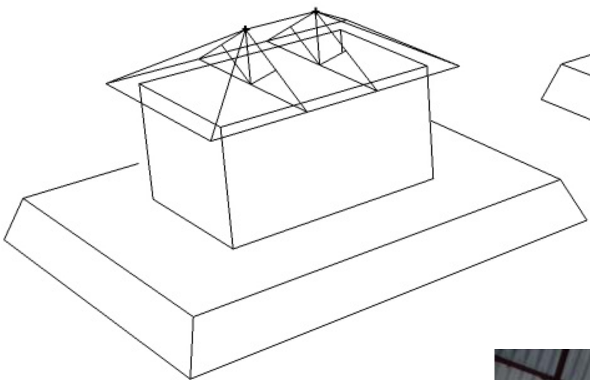
D.5.17 Steelwork must be adequately protected and maintained against corrosion in the saline environment. Ideally it should be galvanised and assembled with bolted connections, but that is very difficult to achieve in the region. Good quality preparation, priming and painting are essential. Site welding is common practice and almost inevitable because of inaccurate construction methods, so it is very important to protect the steelwork from corrosion afterwards. All connections must be thoroughly cleaned and painted after completion.

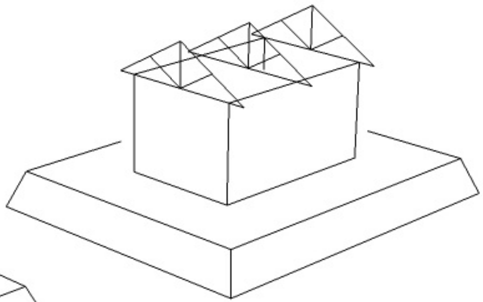
[20] For illustration of hips and gables see p29



Gabled roof
showing three similar trusses

Hipped roof
showing arrangement of trusses





UNDP prototype family shelter showing mezzanine and steel roof

D.5.18 *Mezzanines*

It is common practice for owners to store material in the roof space on makeshift mezzanine platforms made of timber or bamboo. These are sometimes used as sleeping platforms. The UNDP/DFID phase two design has created a large platform space by lifting the roof. The platform has an emergency escape window, which can be used in a severe flood or in the case of tidal surge, by occupants sheltering in the roof space. This design has some features that weaken the overall structure (increased height and end wall openings); but the structure is otherwise very robust and this is a good example of balancing strength with other needs.

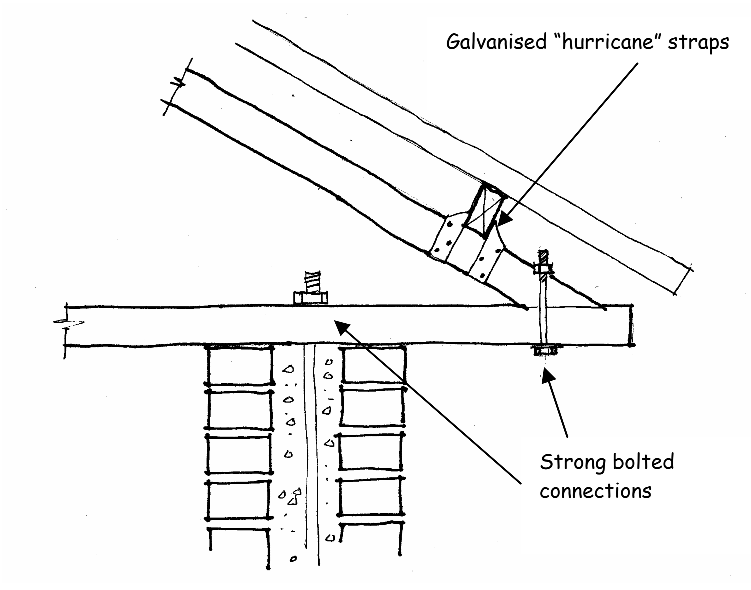
> *Key message*
> It is often necessary to balance structural considerations with other very practical concerns that affect the occupants' lives. This should only be done in consultation with the Engineer.

D.5.19 *Connections*

The traditional fixings used are nails, wire and rope (often jute). All of these corrode rapidly and have inadequate strength. Engineered houses often specify screws, but these are generally hammered in like nails and are therefore a very weak method for fixing timbers together. This makes timber roof construction extremely vulnerable to storm winds unless additional measures are taken, such as metal strapping, and the owners must maintain these.

> *Key message*
> No roof is cyclone resistant if it is not robustly anchored to a sufficient mass. It is essential to anchor any roof construction to the walls or posts as well as practically possible.

D.5.20 Timber roofs are relatively easy to anchor to pre-cast posts by casting in a single bar at the top which is folded over the timber roof member. However, we do not recommend use of these posts, as noted above. Anchoring to brick piers and walls can be achieved using galvanised straps, but these do not appear to be readily available in the region. Therefore it may be necessary to embed re-bars in the piers for roof anchorage. The UNDP/DFID phase two shelters have adopted this detail (see photo 31). However there is very little bond between mortar and re-bar, so it is necessary to ensure the bar is anchored low down in the brickwork. Another difficulty with this approach is that the anchor position is dependant on accurate setting-out of brickwork.



Some good connection details

Reinforced brick piers with a 4” or 5” central concrete core help overcome this difficulty (diagram p30). A lapped bar at the top of the pier can be adjusted in the final pour, and still be effectively bonded to the brick walls by the concrete.

D.5.21 Hook bolts (“J bolts”) are <u>essential</u> for fixing CGI sheets.

D.5.22 In beam & post timber construction it is essential to adequately fix cross bracing, and an Engineer must specify these connections. The fixings must be as durable as possible – such as zinc-coated bolts. The Engineer must also give consideration to roof bracing for wind uplift.

Good anchorage to reinforced brick pier. Note the use of J-hooks to secure the roof sheets.

D.5.23 As discussed earlier, houses must be securely anchored to their plinth. This is achieved in the case of the UNDP/DFID Phase Two units by building in solid brick construction directly over a brick plinth foundation wall, which has enough weight to resist flood and wind pressures. For beam & post construction careful attention is essential to hold down the posts and at the same time make them durable.

UNDP prototype house

Conclusion

If vulnerability is the product of risk and poverty, then Bangladesh is one of the most vulnerable countries on earth. Building houses that are better, stronger, safer and more long-lasting has to be an important step towards reducing that vulnerability. This report insists that core shelters must be built to known standards of safety and durability. Good design and sound engineering don't guarantee a successful shelter programme, but they are essential ingredients in a complex mix.

By learning from local skills and using readily available and affordable materials, stronger, safer houses can be built that are also understandable and easily copied. In this way the benefits of the programme don't remain solely with the occupants of the houses; the wider, majority, community derives benefit as well because builders receive training and improvements get reproduced.

For the families of SW Bangladesh that have lost everything through flooding or cyclone, a new home is a step towards restarting their lives; a new home that is safe and durable is a step towards reducing their long-term vulnerability.

Family outside their new prototype brick home.

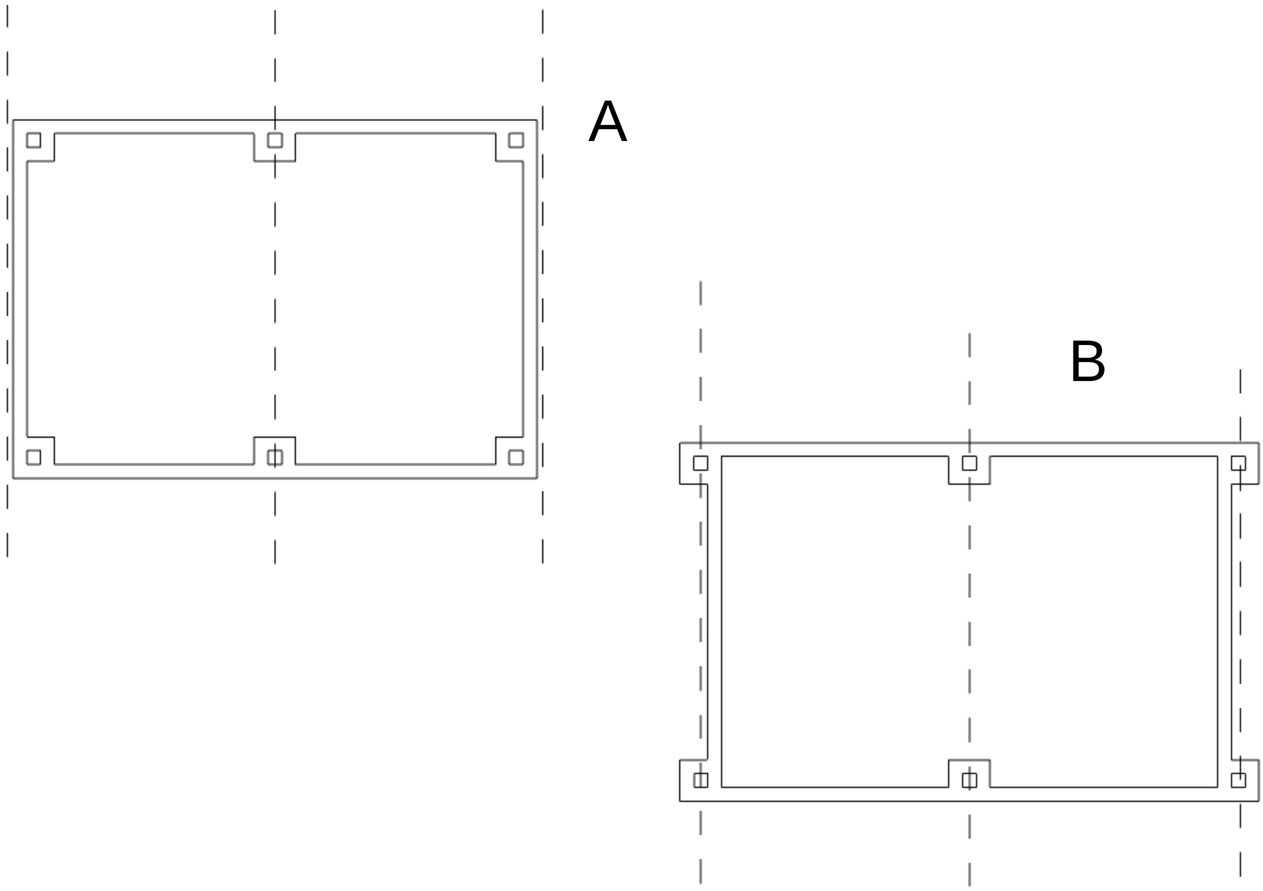
ANNEX ONE

Design of single room brick shelter.

The drawings contained in this Annex were developed by the authors as part of the support for the UNDP/DFID shelter programme. This is not the design that was finally constructed, as certain modifications were made subsequent to our involvement.

These drawings are included here to assist in the design of future post-disaster reconstruction in Bangladesh. However they should not be copied, and anyone using these ideas should obtain independent assurance that the construction techniques and engineering are adequate for their purpose.

ALTERNATIVE PLAN ARRANGEMENT

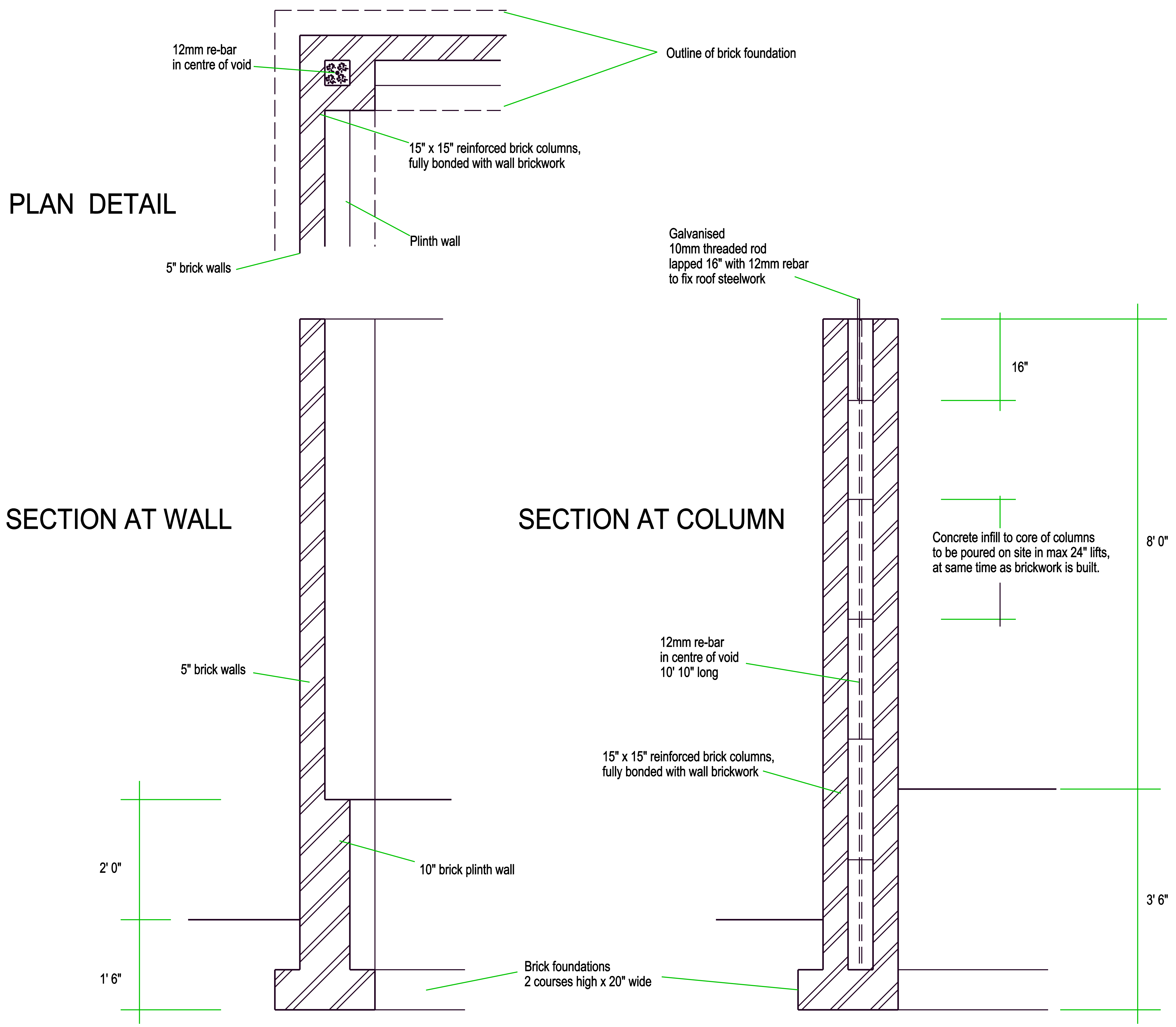


<u>Plan A</u>
15" brick composite columns are inside. The dotted line represents the line of the trusses which are not centred on top of the columns.

<u>Plan B</u>
This arrangement of columns has some advantages:

- The trusses are now in line with the columns,
- The columns take up less of the internal space.

Not to scale. Plan size approx 15' x 10'.



Notes:

On-site concrete infill may use crushed brick aggregate. Aggregate to be max 25mm, well graded, from min Class 2 bricks. Trial mixes to be cast and tested for maximum strength and approved by the Engineer. Refer to the specification

PRELIMINARY
FOR COMMENTS ONLY

Rev	Description	Date

Project

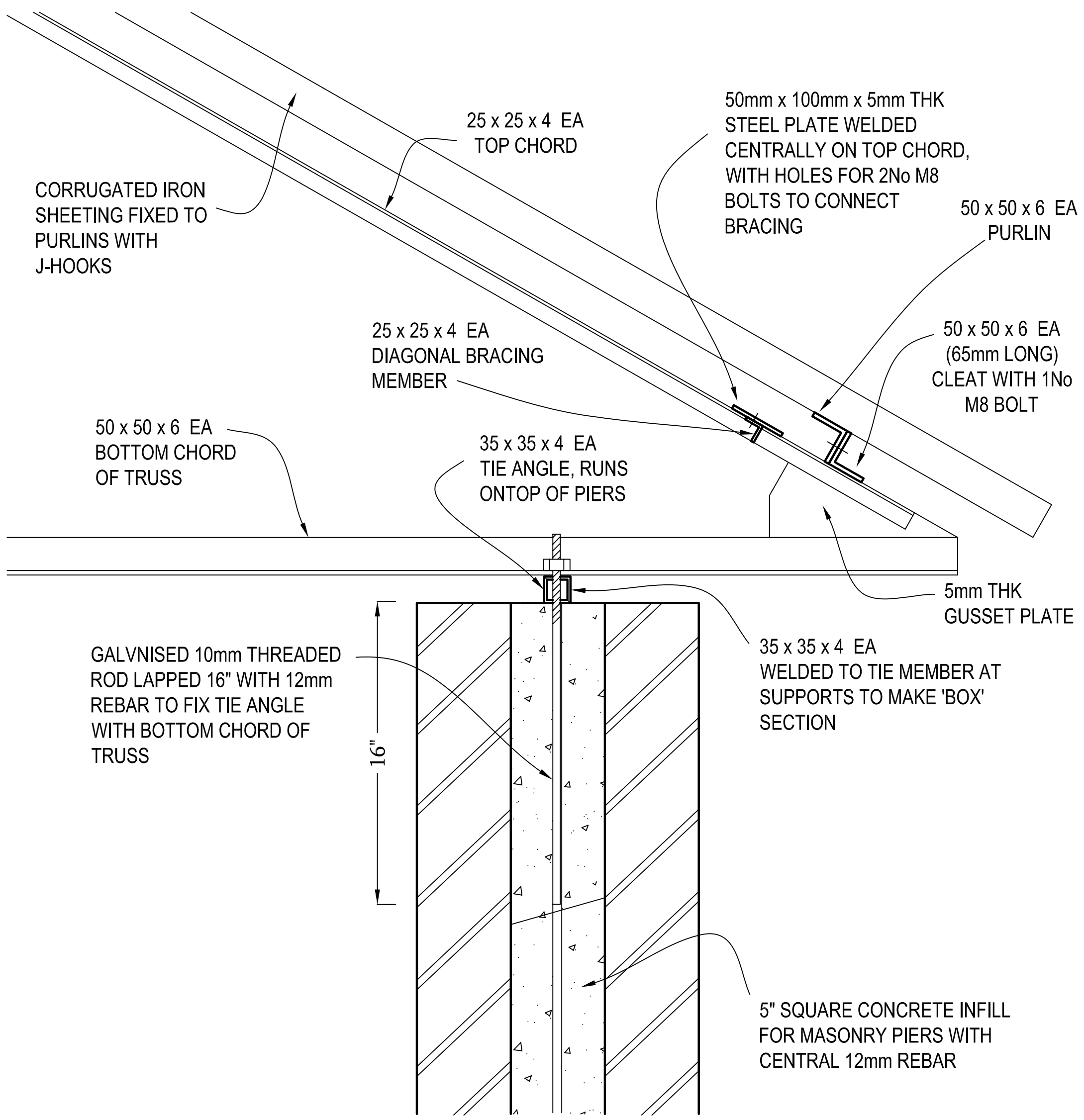
Cyclone Sidr, Bangladesh
Core Houses, Phase 2.
By UNDP / DFID

Title

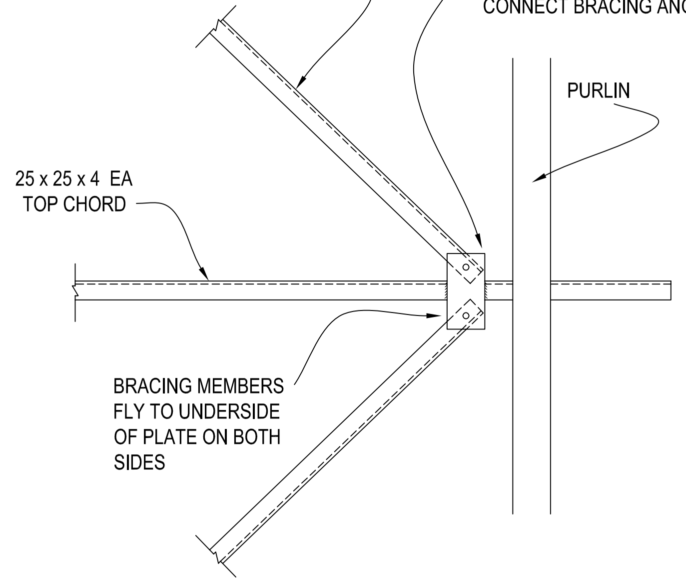
Typical brick column
and foundation details

Scale	Date	
1:20 @ A3	20 Feb 09	

Project No.	Drawing No.	Rev
BF2	S310	P1



CENTRAL TRUSS END DETAIL
(ELEVATION)
(1:10)



BRACING CONNECTION DETAIL
(CENTRAL TRUSS - PLAN)
(1:10)

Notes:

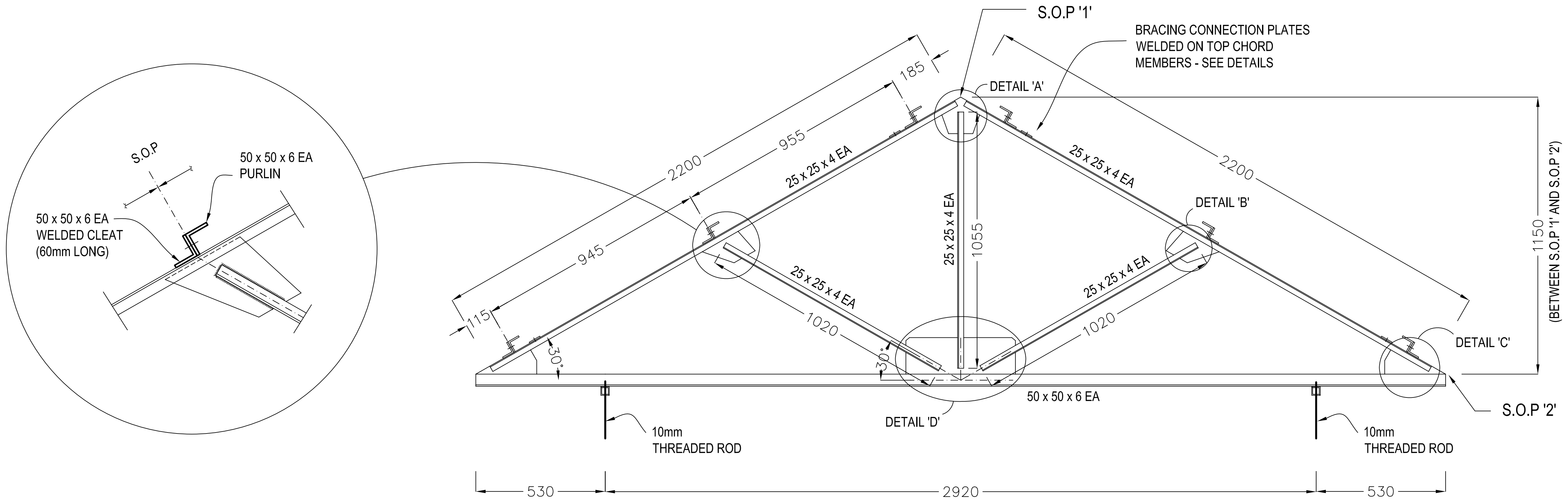
- Do not scale from this drawing! Please ask if in doubt
- All gusset plates to be 5mm thk Mild Steel
- Minimum 6" weld lengths for all Angles onto gusset plates.

Project: Cyclone Sidr, Bangladesh Core Houses, Phase 2. By UNDP / DFID

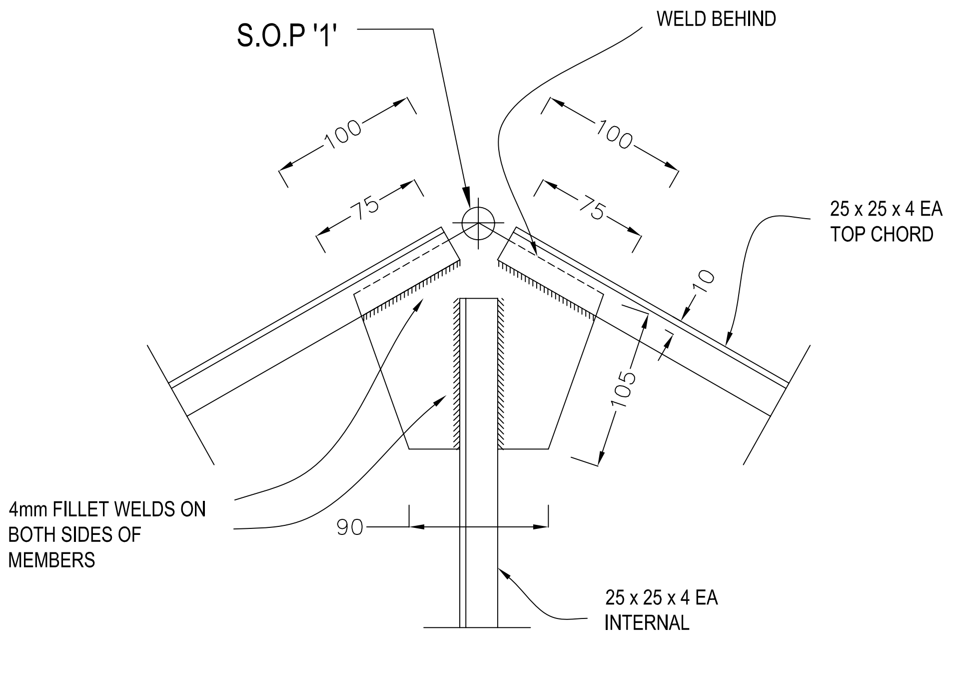
Title: Proposed Steel Roof Trusses - Details

Scales	Date
AS SHOWN @ A3	Feb '09
Project No	Drawing No.
4062BF2	S 312

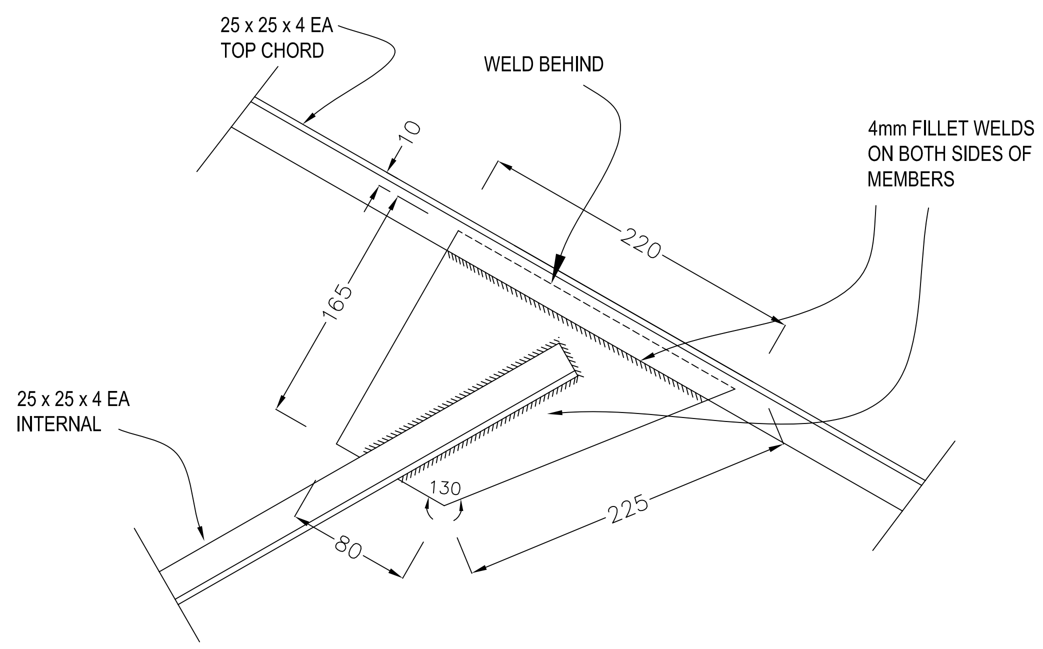
STRUCTURAL SOLUTIONS
The Chapel House, 11a Alexandra Park, Redland, Bristol, BS6 6QB, tel. 0117 924 5014, fax. 0117 924 5207
The Warren, Main Street, Keevil, Wiltshire, BA14 6ND, tel. 01380 871 410, fax 01380 871 630
email: admin@structuralsolutions.co.uk



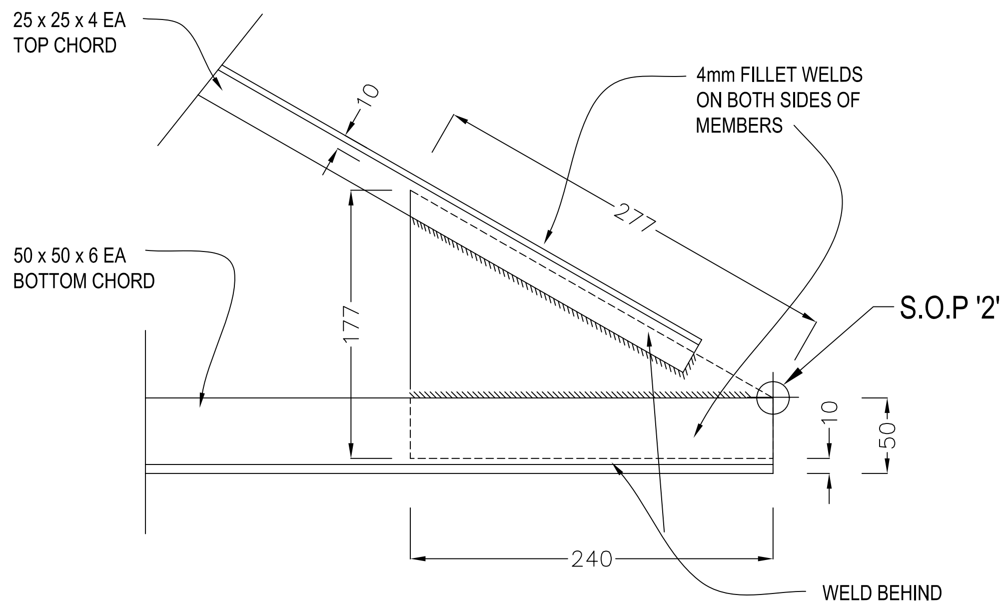
TYPICAL TRUSS ELEVATION
(1:20)



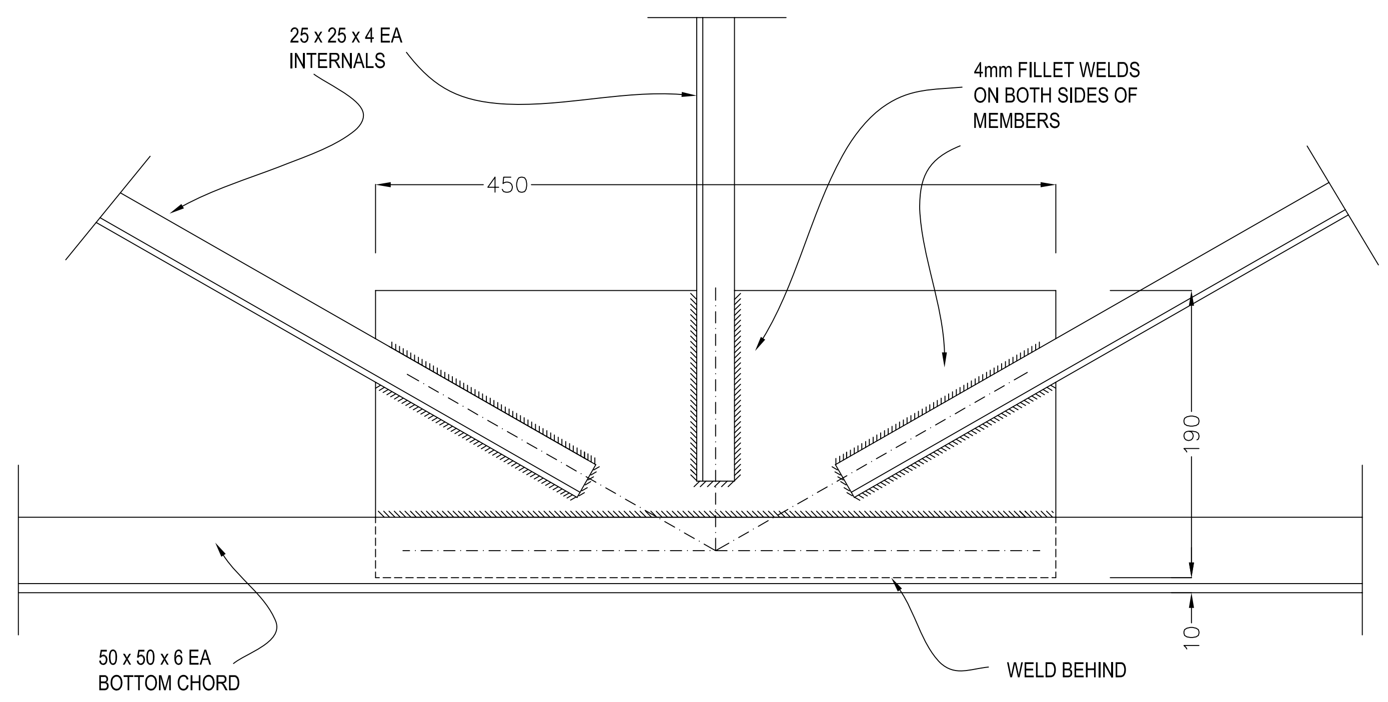
DETAIL 'A'
(1:5)



DETAIL 'B'
(1:5)



DETAIL 'C'
(1:5)



DETAIL 'D'
(1:5)

Notes:

- Do not scale from this drawing! Please ask if in doubt
- All gusset plates to be 5mm thk Mild Steel
- Minimum 4" weld lengths for all Angles onto gusset plates.

Key :

S.O.P - Setting Out Point

Rev	Description	Date
A	Minor additions, paper size increased, scales changed	06.03.09

Project: Cyclone Sidr, Bangladesh Core Houses, Phase 2. By UNDP / DFID

Title: Proposed Steel Roof Trusses - Fabrication Details

Scales	Date	
AS SHOWN @ A2	Mar '09	
Project No: 4062BF2	Drawing No.: S 313	A

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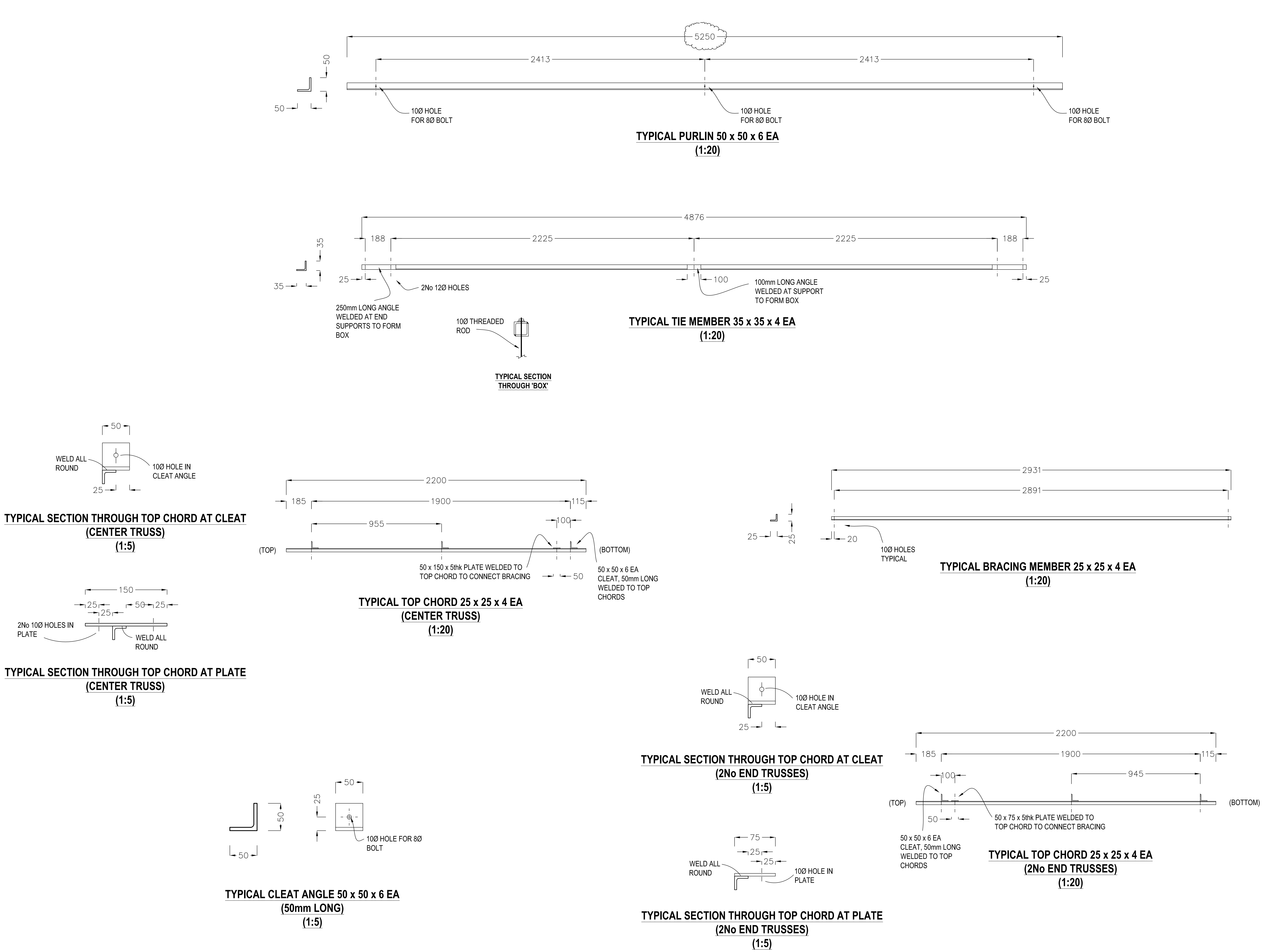

Notes:

- Do not scale from this drawing! Please ask if in doubt
- All gusset plates to be 5mm thk Mild Steel
- Minimum 4" weld lengths for all Angles onto gusset plates.

Subject to sheet size ??

Rev	Description	Date
A	Minor amendments	06.03.09

Project
Cyclone Sidr, Bangladesh
Core Houses, Phase 2.
By UNDP / DFID

Title
Proposed Steel Roof Trusses - Fabrication Details

Scales	Date	
AS SHOWN @ A2	Mar '09	
Project No	Drawing No.	
4062BF2	S 214	A

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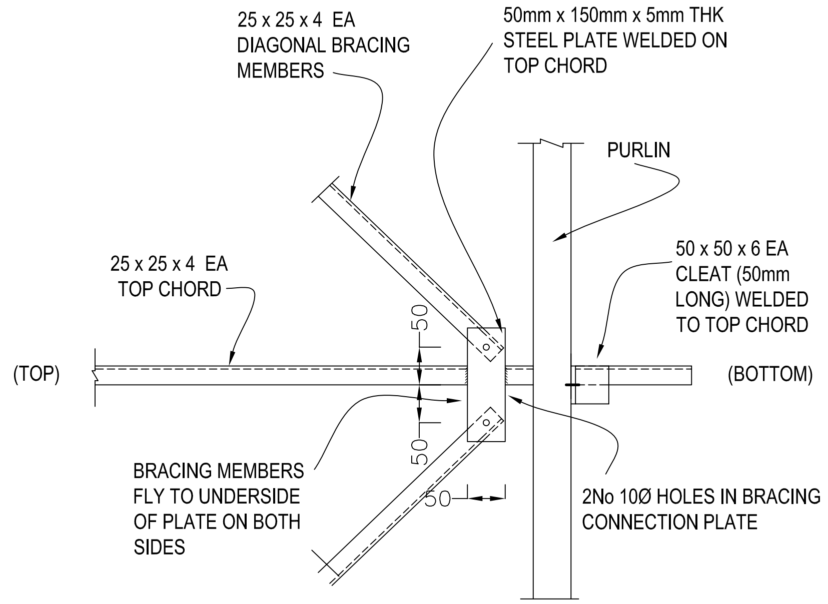
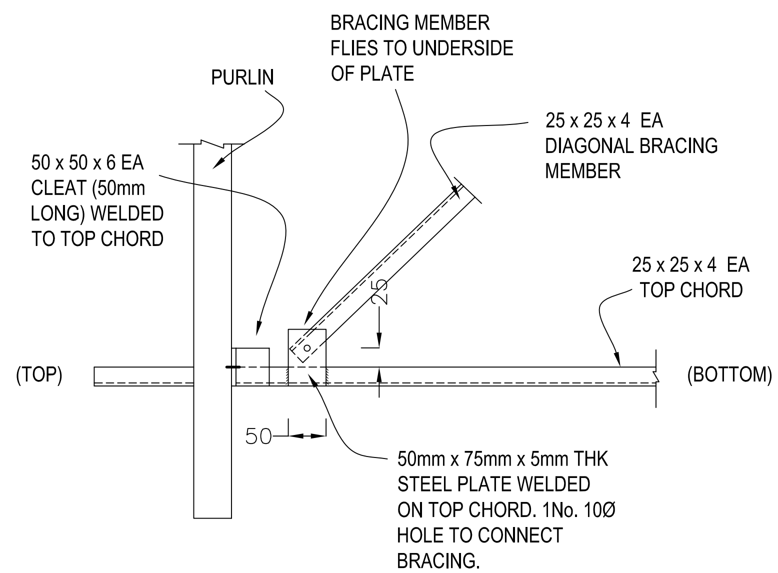


BRACING CONNECTION DETAIL
(CENTER TRUSS - PLAN)
(1:10)



BRACING CONNECTION DETAIL
(2No END TRUSSES - PLAN)
(1:10)

Notes:

- Do not scale from this drawing! Please ask if in doubt
- All gusset plates to be 5mm thk Mild Steel
- Minimum 4" weld lengths for all Angles onto gusset plates.

Rev	Description	Date
B	Brace plate sizes revised	06.03.09
A	Detail for end trusses revised	04.03.09

Project: Cyclone Sidr, Bangladesh Core Houses, Phase 2. By UNDP / DFID

Title: Proposed Steel Roof Trusses - Fabrication Details

Scales	Date	
AS SHOWN @ A3	Mar '09	
Project No: 4062BF2	Drawing No.: S 315	B

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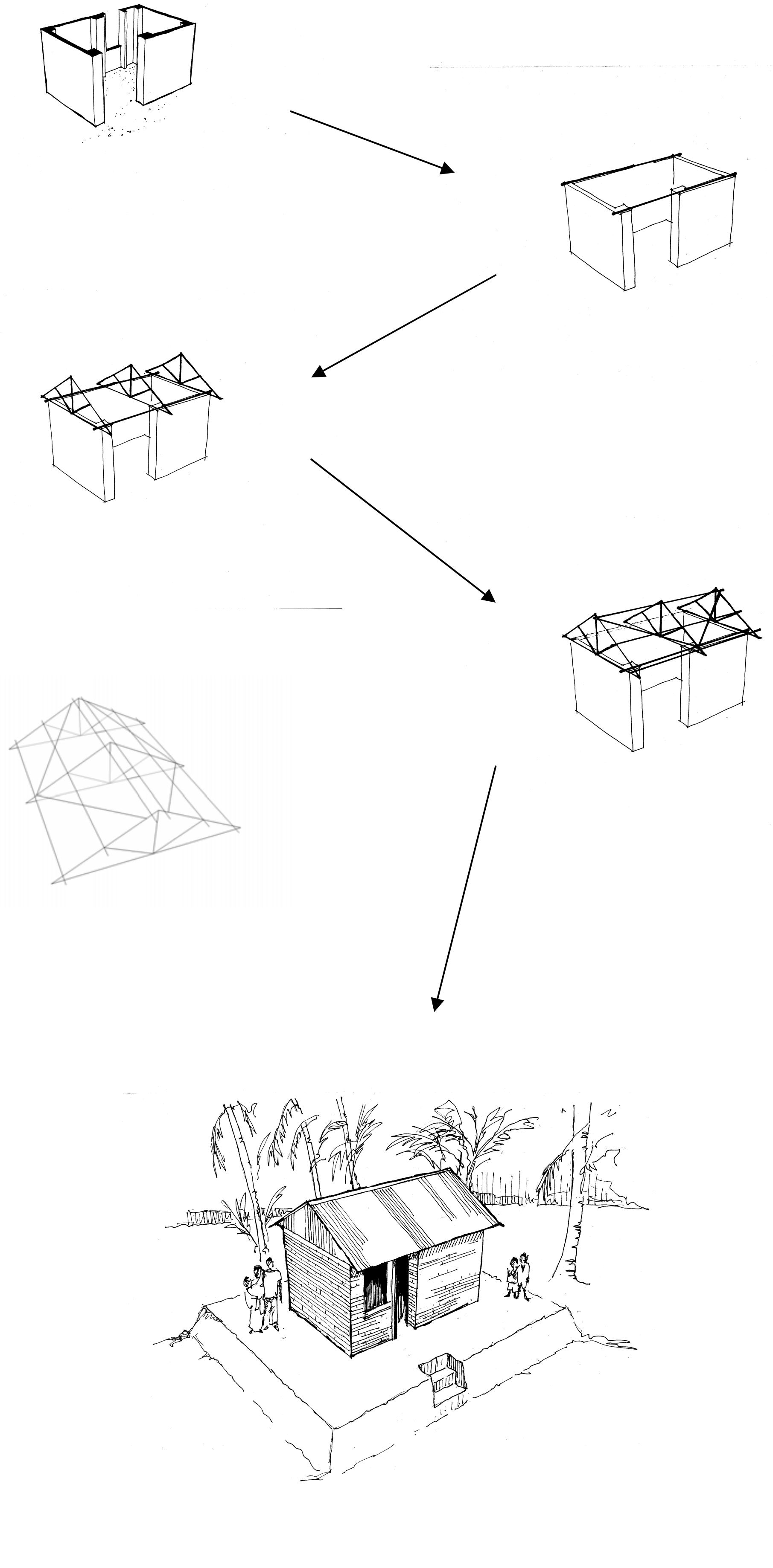
email: admin@structuralsolutions.co.uk



ANNEX TWO
Presentations

A workshop was help in Dhaka on Monday 30 March 2009. Several agencies made presentations on their post-Sidr reconstruction programmes. Click on the links to see the corresponding presentation.

UNDP – United Nations Development Programme
ACF – Action contre la Faim
CARE Bangladesh
Muslim Aid
Islamic Relief
BRAC University
Habitat for Humanity
UK Consultants

ANNEX THREE
Selected Blibliography

For further reading we suggest the Shelter Centre library. This has a wealth of information available on-line.
http://www.sheltercentre.org/library

The proceedings of Housing and Hazards workshops can be accessed via the website below. This is a collaboration between Exeter University,UK, and the Bangladesh University of Engineering and Technology (BUET).

- Communicating Housing Technologies in Low-income Areas
- Implementing Hazard Resistant Housing
- Village Unfrastructure to cope with the Environment
- Housing & hazards conferences 1996 and 2000

www.housingandhazards.org

Handbook on Design and Construction of Housing for Flood-prone Areas of Bangladesh – Asian Disaster Preparedness Center (ADPC)
http://www.adpc.net/AUDMP/library/housinghandbook/handbook_complete-b.pdf

Battling the Storm – A study in Cyclone resistant Housing – Bashirul Haq
http://www.sheltercentre.org/library/Battling+Storm+Study+Cyclone+Resistant+Housing

ANNEX FOUR
Technical terms explained

These are simplified explanations of some of the terms referred to in the report.

<u>Timber structures:</u>

Beam &post – a common form of timber framing normally using 4”x4” columns and beams.

Framing – this uses smaller sections (3”x2”) but more closely spaced.

Cross-bracing- diagonal timber or steel that makes the structure rigid (*triangulation*).

<u>Roof structures:</u>

For illustration of *hipped* and *gable* roofs, see page 29.

A roof *truss* can span greater wall-to-wall distance than *rafters* on their own, and can resist greater wind loads.

A purlin spans between trusses and carries the roof sheet or intermediate rafters.

J-hooks are hooked bolts that securely fix CGI sheets to purlins and/or purlins to rafters.

<u>Columns and piers.</u>

A *column* (also sometimes referred to as a post) is freestanding, while a *pier* is integral to a masonry wall.

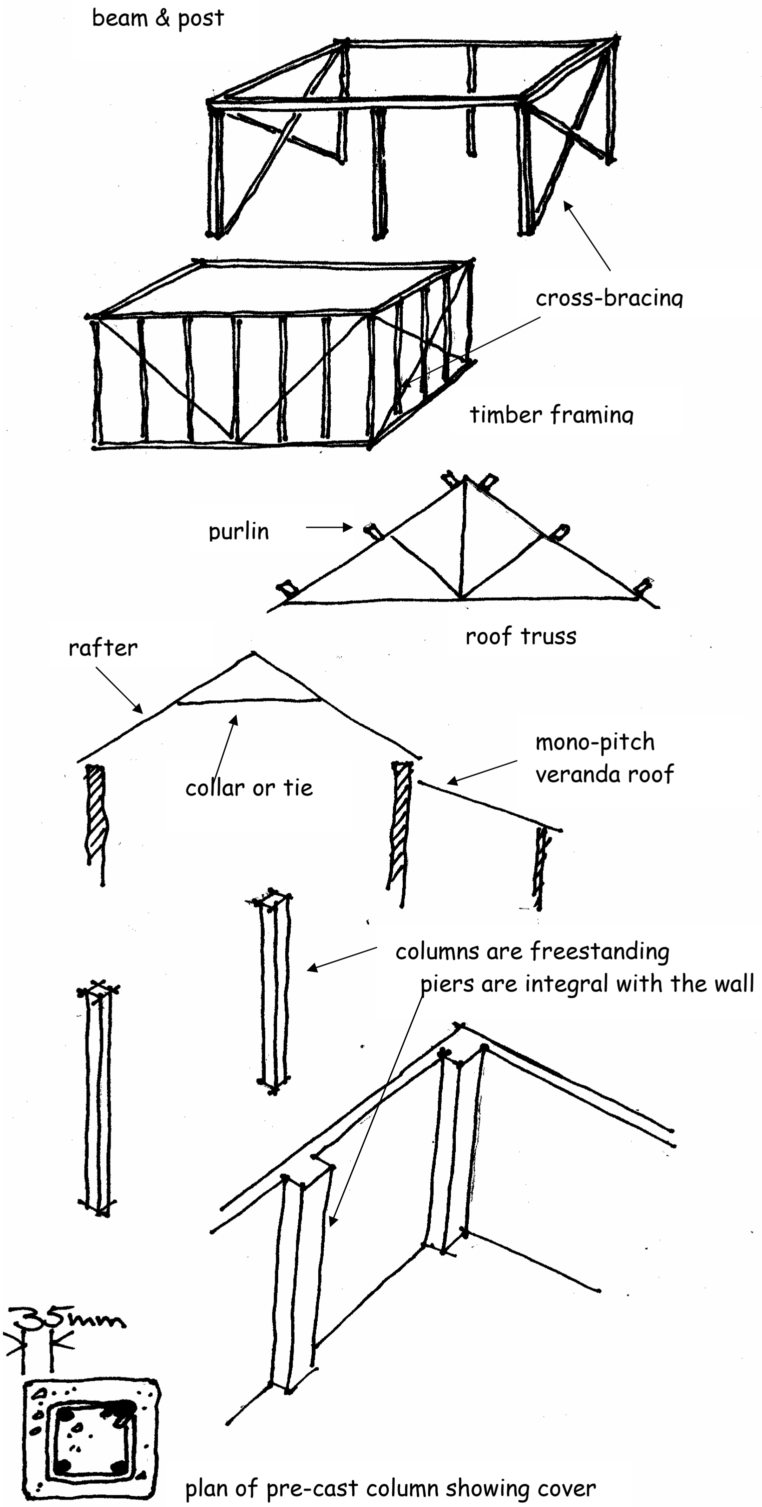
<u>Reinforced concrete</u>

Pre-cast means made off the site in a controlled workshop or yard.

In-situ means cast in place at the building site as part of the construction.

Curing – concrete must not dry out while hardening or setting. During the curing process it must be kept damp for several days.

Cover – there should be at least 35mm of concrete covering the reinforcing steel.



plan of pre-cast column showing cover of reinforcing steel