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Project Site Visits ~ Aceh

Leprosy Communities at Trienggadeng and Po Diamat Villages

By
Sjoerd Nienhuys, Architectural Engineer
Shelter Advisor, Trócaire (Ireland)

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Abstract

The Tsunami Relief and Rehabilitation Programme, set up following the devastating tsunami of 26 December 2004, allocated large international financial support to the reconstruction of houses lost in the disaster. The Aceh district of Sumatra in Indonesia was hard hit and many national and international organisations provided assistance in the reconstruction. Site visits were conducted to Trienggadeng and Po Diamat villages where respectively 59 and 35 permanent houses are being built for the leprosy communities by Cordia Medan, a new NGO. The earthquake- and tsunami-resistant properties of the houses are assessed and recommendations provided to increase occupant safety, improve structural strength and have the correct application of the national code for earthquake-resistant reinforced concrete design. Special attention is given to the reinforced column design of the houses on stilts because they are the key factor for the safety of the occupants. Observations are made with regard to interior climate of the houses and site planning.

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Photographs and drawings: Sjoerd Nienhuys
Document editing: Doreen J. Nienhuys

1. INTRODUCTION

On 13 and 14 February 2007, field visits were made to the Cordia Medan projects at Trienggadeng and Po Diamat villages where respectively 59 and 35 permanent houses are being built for the leprosy communities. Trienggadeng village is located three hours from Banda Aceh along the north coast, while the village of Po Diamat is located in Banda Aceh near the large Banjir Kanal Kreung Aceh (canal) and close to the shore.

During the site visits to various projects, common shortcomings could be observed in some house constructions and are elaborated upon in this report, using information and photographs derived from various NGO building sites (not only Cordia Medan). The technical assistance focussed mainly on those houses under construction, as changes to completed houses have limited possibilities.

Explanation of Earthquake-Resistant Design Principles

This report covers some basic principles of earthquake-resistant designs and the correct application of reinforced concrete in the building construction. These principles are applicable to all houses built either by contractors or through self-help. In addition, the details can be used to develop instructive manuals for training contractors and building inspectors.

CAP Permanent House Drawings

Cordia Medan was provided with BRR[1]-approved CAP (Community Action Plan) permanent house drawings for the implementation of their reconstruction project. These CAP drawings were foreseen with GTZ Germany and Caritas Germany logos on each page. This suggests that the drawings had been made by CAP under their supervision and all the technical details provided had been controlled for accuracy. Relying on this certification, Cordia Medan followed the CAP permanent house design.

However, a number of observations presented in this paper pertain to the shortcomings of the design of the reinforcement and its application. Detailed section drawings and reinforcement bar cutting-folding schedules were lacking. Insufficient experience of the contractor realising the construction work and lack of supervision by the implementing organisation caused faulty reinforcement.

Without proper detailing and application of the reinforcement design, the reinforcement might not add the required strength to the building and, possibly, might even weaken the construction. Once the concrete is cast, the actual reinforcements inside the concrete cannot be seen. For that reason, not only must the drawings be accurate, but also inspection is required after completion of the formwork and before casting the concrete. In practice, this means that almost permanent site inspection is necessary.

If an international organisation allows the use of its logo on design drawings, they should be responsible for the accuracy of the technical information and design specifications; otherwise, it gives a false sense of approval or correctness. In such a case, the less experienced implementing organisation will not re-verify the technical data, but implement the construction work according to the given specifications.

[1] BRR = Badan Rehabilitasi dan Rekonstruksi (Reconstruction and Rehabilitation Agency of Indonesia).

2. TRIENGGADENG VILLAGE

2.1 Settlement Committee (Association)

The original village of the leprosy community was completely destroyed. The community needed a hygienic environment and so it was decided to relocate the village. The Parish of Sacred Heart Banda Aceh purchased four hectares of land with funds from Italian donors, coordinated by Fr. Ferdinando Severi. The land title issue has been settled through the Department of Land Title and Land Rights (BPN)[2].

> "Learning from several cases experienced by several NGOs where the beneficiaries sold the donated houses and then claimed the need for housing and shelter to other NGOs, it was discussed and agreed among Cordia, Caritas Germany and the Parish of Sacred Heart Banda Aceh that the land title on individual villagers will be given to the community after a period of 5 years. Parish of Sacred Heart will hold the land title temporarily, before passing the land right to the villagers." (Source: Cordia Medan Report)

Experience from many settlement improvement and squatter upgrading projects has shown that low-income people will often sell their new (donated) property and return to their former situation as squatters or renters. When new houses are provided to renters, these renters should preferably continue to pay rent (at the same rate as in the past) for their new houses. For sustainability, the overall management and maintenance expenses of a new settlement should be borne by the community as a whole; income from rent will assist to generate funds for this purpose. Community services can only be satisfactorily created and maintained when the entire community participates in its management through organisation, income generation and implementation.

Recommendation
Forming a settlement committee or an association of house owners (cooperative) to manage the cluster of houses and its infrastructure as a group, under the supervision of Cordia Medan, should be considered. This way the villagers (cooperative) will learn how to manage the infrastructure and to raise funds for its maintenance. The handing over of individual plots and houses to the occupants should remain conditional to general settlement occupation and management rules that can be developed over the five-year period. The association of house owners can set rules for new members or departure of members, credit union, small enterprise and extension of the infrastructure.

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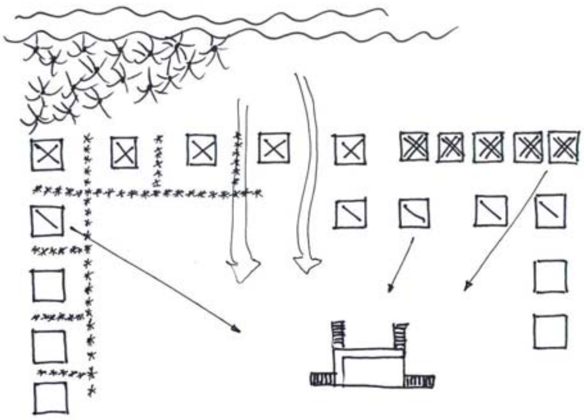
[2] BPN = Badan Pertanahan Nasional (National Land Agency).

2.2 Village Planning

Overview of Trienggadeng Village

The houses of Trienggadeng village are situated in a U-shape around a central park area with coconut trees (left in photo above). The total land area is four hectares, with the individual plots measuring about 10 m x 20 m. The distance from the sea of the line of houses shown in the middle of the photo above is not very great. The house on the far right is located in the second row of houses. The houses seen behind the coconut trees (left) are in a line perpendicular to the coast. The possible recurrence of a similar, large-size tsunami has not really been considered as the land is only slightly above the high seawater line. Along the coastline, a small dike has been created to protect the village from small tsunamis.



Recommendation

Apart from the small dike on the coast, four other measurements can be taken to improve disaster preparedness for this site.

1) *Dense plantations should be realised between the shoreline and the houses.*
2) *No extensions should be built between the houses, obstructing the flow of onrushing seawater.*
3) *No fences or barbed wire barriers should be erected in between the houses, blocking escape routes towards safer locations.*
4) *An elevated construction or communal building on columns should be erected in a central location with easy access from all sides. The ground floor columns of that building should be self-supporting and have no infill walls.*

2.3 Kitchen Extension

The 59 houses, some with wheelchair ramps for the disabled, are almost completed. It has been decided to add a kitchen on the rear platform of the houses, next to the WC, because the occupants (ex-leper patients) would have no financial means to realise this themselves. The kitchen extension has been designed with a wooden post and a masoned wall. The timber roof support has been fixed with a nail into the plaster of the house. However, with an earthquake, this will come loose immediately. In addition, the joint between masonry and timber post will always remain visible.

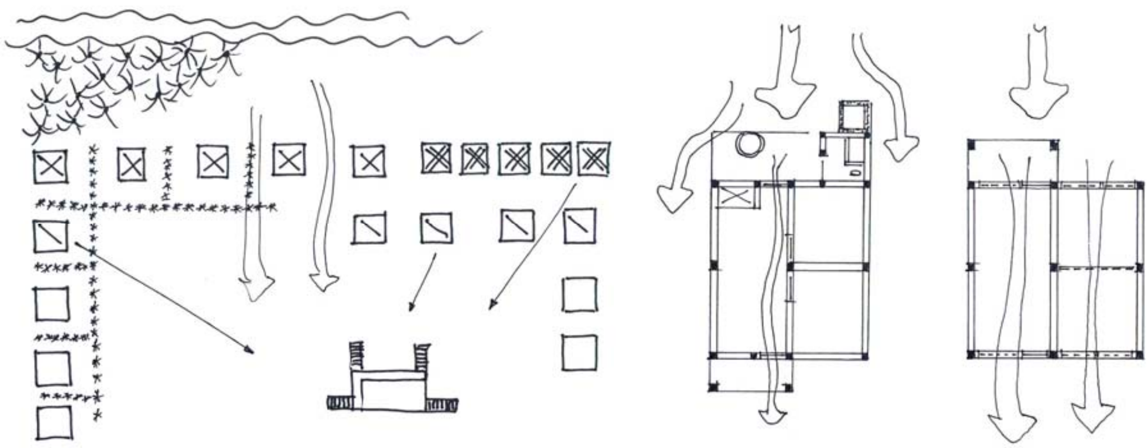
Kitchen Extension at Rear of House

Recommendation

The kitchen extension should be made by using a masoned wall with an infill stiffener column of 10 cm x 10 cm (instead of the wooden posts). Over the top of the wall, a reinforced concrete stiffener beam 10 cm x 6 cm thick should be cast with two 10 mm bars. These two bars need to be connected into the reinforced columns of the building by opening the concrete and filled in after attachment.

2.4 Wall Construction – Reinforcement Options

Most of the houses in Trienggadeng village have the back entrance facing towards the shore, providing a perfect opportunity to reinforce that side. In the sketch below, the houses with a double cross are the most vulnerable in the event of another large tsunami, those with a single cross less vulnerable, and the houses with a diagonal the least vulnerable.



No one can predict the size of the next tsunami or how much advance warning there will be, but the additional reinforcement to the rear of the house is a simple option that might give the house enough strength to withstand a small tsunami and save the lives of the occupants if they cannot escape in time.

The toilet extension with the water basin is actually a very strong construction because of the cross walls supporting the front-facing wall. This may deflect the water flow. To enhance the strength of the kitchen wall, a cross wall should be made, reinforced with a concrete tabletop. This can be made in the existing house or in the new kitchen extension.

For those houses with the porch facing towards the sea, the best option is to have large openings in the walls perpendicular to the flood flow. The walls should be of light materials that will be knocked out of the building frame by the tsunami wave, letting the water pass through the house. Obviously, any occupants on the ground floor need to escape to a higher level; otherwise, they will be taken along with the water flow and accompanying debris.

First semi-permanent house designs realised by NGOs along the north and east coast of Aceh.
These houses are well designed – structurally and climatically.
However, in a tsunami-risk area, houses should not be built too close together
nor should the spaces between the houses be clogged up with structures that will obstruct water flow.

3. PO DIAMAT VILLAGE

Because the original Po Diamat settlement was located on the seashore and destroyed by the tsunami, the residents now live in barracks. Being so prone to a future tsunami, Fr. Ferdinando strongly recommended that the community be relocated. However, the local community of the proposed location rejected the presence of a leprosy community in their vicinity[3]. Finally, it was decided to reconstruct the houses on the original village site.

The houses in Po Diamat are being built on columns (stilts), elevated about one metre above the ground (1.5 metres above sea level). This house design is very appropriate for the location as it is quite close to the sea. The elevated houses probably can withstand a small tsunami and are certainly high enough to safeguard the occupants against seasonal flooding. However, they do not provide sufficient clearance for a tsunami the magnitude of December 2004, but most people consider such a recurrence unlikely.

Few houses being built by the many NGOs in the Aceh region would meet the criteria of withstanding a similar tsunami (avoid collapsing). The best method to prevent loss of lives is an early warning system with nearby escape routes to higher ground. In Po Diamat, however, there is no nearby higher ground and the construction of a raised community centre might be a consideration (see Trienggadeng sketch on page 3).

The villagers thought the new design was better than their former semi-permanent houses lost in the tsunami; the main reason being that the new house is made from concrete. Conceptually, reinforced concrete is considered by villagers as a durable material, but factually, it can be a very dangerous material if the construction is not well designed or properly constructed.

As understood from the project staff, the design drawings were supplied through the CAP (Community Action Plan) programme, but some adjustments were suggested by the BRR, in particular, to increase the reinforcement in the columns and beams. The result is a simple, elevated house design using a reinforced concrete frame structure with brick infill walls and having adequate strength to resist moderate earthquakes.

The photo right is a Cordia Medan house in Kuala Keureuto Barat village. The same type house is planned for Po Diamat. The elevated house has nine columns under the central section and four under the landings, in total thirteen supporting columns and two staircases.

(Photo by Cordia Medan)

[3] In many situations throughout Aceh, relocation of houses was not realised due to lack of land, insufficient compensation of the negative aspects of the relocation, slow decision-making processes on relocation sites and infrastructure, and other reasons (such as with integration of the leper colony into other communities).

4. BUILDING MATERIALS AND INTERIOR CLIMATE

Materials Increase or Reduce Potential Earthquake Forces

The force of an earthquake is directly related to the weight or mass of the building. The heavier the building materials, the larger the forces will be between the ground acceleration and the upper construction.

Using heavy building materials (reinforced concrete, cement blocks, stabilised soil-cement blocks, plastered burned brick, and clay or cement roofing tiles) increase the earthquake forces in comparison to lightweight materials (timber, plywood, bamboo, wattle, zinc or aluminium roofing sheets[4]). By making the building lighter and reducing its overall weight, the same building will be relatively stronger.

Use of Renewable Resources

The use of timber and other lightweight materials is advised for earthquake-resistant designs, but these materials may not be readily available. Especially the supply of good quality (legally) sawn timber is becoming increasingly limited and costly. In terms of energy consumption, both reinforced concrete (cement, steel and transport) and burned clay bricks (firewood, cement mortar and transport) constructions have high-energy demands and therefore considered environmentally unfavourable. On the other hand, good quality reinforced concrete and reinforced burned brick constructions are long lasting (+50 years). The energy balance will tilt further negative if, due to the overall design of the house, air-conditioning and ventilators are required to keep the occupants comfortable.

With the use of permanent materials lasting 50 to 100 years or more, the chances of the buildings being affected by strong earthquakes or another tsunami increase. When the reinforced concrete construction is poorly executed by the contractors, it may fall apart by itself in 10 years due to corrosion of the steel.

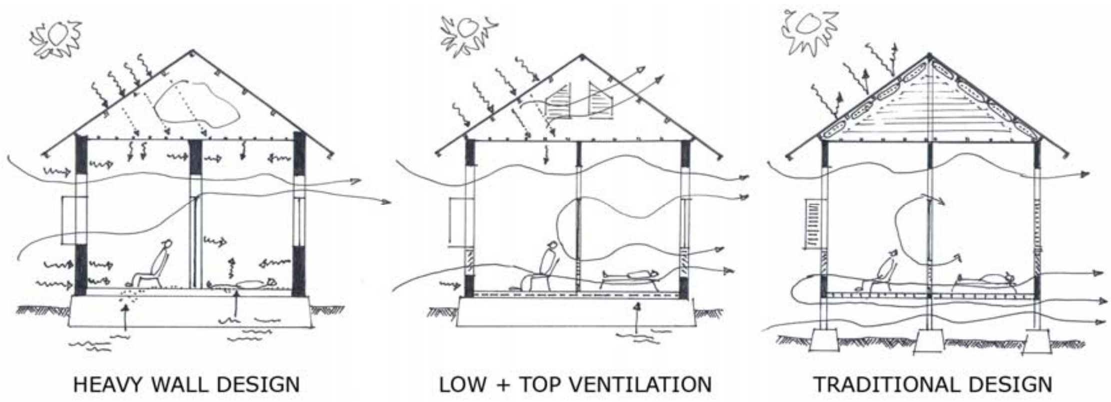
The reinforcement of the foundations in the above photos (houses very near to the Aceh east coast) is not adequately covered with good quality concrete. In addition, the plastering will not provide sufficient protection against the salty sea air. Such construction quality will self-destroy due to corrosion.

[4] Traditional materials for house building include timber and bamboo. Good analysis of these earthquake-resistant and climatically appropriate designs can assist in making better house designs.

Climate-Related Design Consideration

The internal climate of the house after construction determines to a large extent the comfort level of the occupants. Traditional houses in tropical coastal areas are usually lightweight timber constructions having a small own mass and therefore rapidly cool off at night. Heavy concrete and stone constructions have a larger mass and heat storage capacity. Consequently, the house takes a long time to cool off at night.

The large ventilation openings in traditional houses rapidly cool off the houses, whereas the newer "modern" stone buildings usually only have small openings and often insufficient cross ventilation. These "modern" houses will take a long time to cool off in the evening, rendering them often uncomfortable during the hot humid periods of the year. Yet, many people favour the solid and heavy stone-type buildings above lightweight constructions because rich people are living in these types of houses.



Heavy Wall Design has large heat accumulation during the day and requires good ventilation to cool off the walls. Because there are no low ventilation openings, warm air is removed only from under the ceiling. With lack of ventilation under the roof, the ceiling gets very warm and heats the rooms. The cement floor does not stop rising moisture from the ground, making the rooms moist.

Low + Top Ventilation is introduced. Plastic foil is placed under the floor before casting, keeping the cement floor dry. The walls are less heavy and the internal wall is lightweight for rapid cooling in the evening.

Traditional Design has all the properties of a comfortable house. Because the lightweight floor is raised, it cools off rapidly in the evening. When metal roofing sheets are used, thermal insulation can be placed under the roofing sheets to stop the heat radiation.

Lightweight Internal Walls

Lightweight construction components are therefore not only suitable in earthquake aspects but also for the hot humid climate. Internal walls can be made from (asbestos-free) fibre-cement board or plywood, both low in weight. Use of these materials translates into a weight reduction of 7-8 ton for a ground-floor-only house or 25%, equally reducing the earthquake forces by 25%.

The photo right shows a room with the internal wall made of plywood. As can be seen, the finishing can be very good, thus reducing the lower image of plywood. In this case, the owner has applied a decorative stencil to the wall.

Using (asbestos-free) fibre-cement boards for internal walls has several advantages:

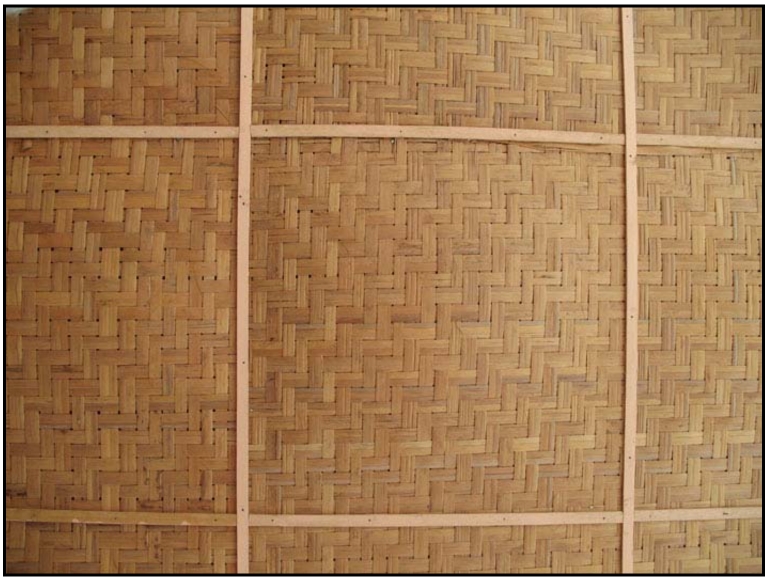
- Fast construction due to less transport needs and easy on-site assembling.
- Lighter own weight and therefore less need for reinforcement.
- Lighter material and therefore cooling off faster in the evening.
- Lower construction cost than heavy brick and cement-plastered walls.

In the photo (right), the internal walls of the house are made from light-gauge galvanised steel profiles onto which both the fibre-cement wall panels and ceiling panels are fixed. The joints between the sheets are smoothened with plaster, after which a coat of paint is applied.

Lightweight Ceilings

The use of local materials can reduce costs as well as weight. Bamboo ceiling panels are decorative as well as lightweight. For durability, they can be varnished and their natural beauty maintained.

When plywood panels are used they need to be whitewashed on both sides before fixing to the ceiling, otherwise they will start to deform after some time due to the humid sea climate.



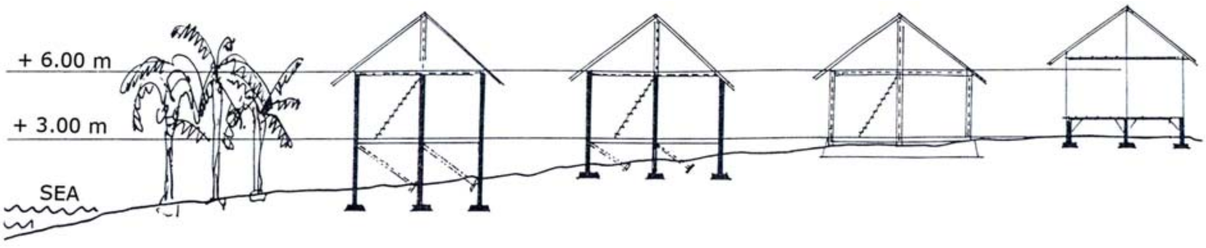
Recommendation

Internal walls and ceilings should be made of lightweight materials, such as plywood, asbestos-free fibre-cement boards (Kalsiplank, Eternit) or bamboo mats. This reduces not only the force of an earthquake, but the room cools off faster in the evening.

5. OBSERVATIONS AND RECOMMENDATIONS

5.1 Foundation Columns (Stilts)

One of the lessons learned from the 2004 tsunami is that houses built on columns (stilts) are safer than houses built directly on the ground. The height of the floor above the average sea level and the distance from the shore determines the safety of a house and its occupants. The Po Diamat location is very vulnerable, being low, flat open land. With the current one-meter elevation above the soil level, this height provides sufficient clearance for common flooding or a small tsunami. However, considering the height of the past tsunami in the reconstruction zone, the height of the first floor should have been preferably three meters above the average sea level.

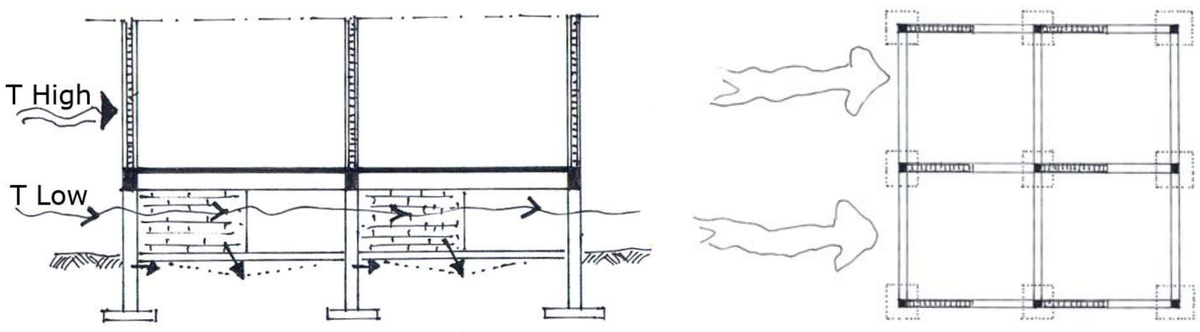


The coastal soil in Po Diamat between the surrounding fish tanks has shifted regularly over the years and is rather sandy. While the 13-column structure seems to be adequate, the footings under the columns are only 60 cm x 60 cm, giving doubt to their bearing capacity in the sandy soil. During a prolonged earthquake, the sandy soil can easily settle under the small footings, with a destructive result. Neither the heavy floor ring-beams nor the 12 cm thick reinforced concrete floor may be able to withstand the settlement of a few columns and crack. The one-meter depth of the column footings, however, is adequate against scouring by moving water.

Recommendation
The column footings on the sandy soil along the coast should be minimal 80 cm x 80 cm.

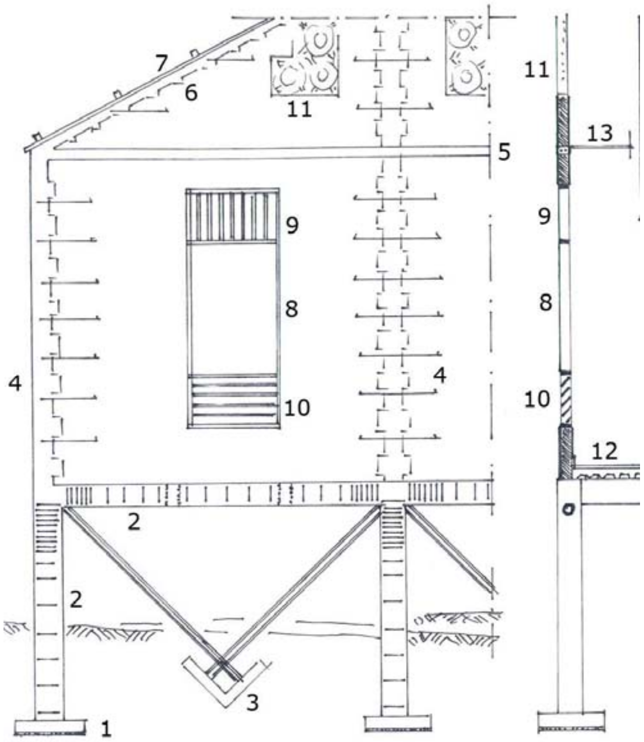
If another tsunami hits higher than the floor level of these houses on stilts, the bottom columns will not be able to withstand the horizontal pressure (load) and break off under the ring-beam because the tsunami load is about 10 times greater than an earthquake force.

Recommendation
To resist another high tsunami that reaches above the elevated floor level, bracing walls or supporting diagonals should be placed between the stilt columns.



The above sketch illustrates an additional support wall built under the floor and against the columns, in the direction of the land. The foundations of these bracing walls need to be adequate to receive a vertical load without the risk of settling.

The sketch below illustrates supporting diagonals using three-inch heavy-duty GI water pipes anchored into a sub-surface foundation. These supporting diagonals block and resist a diagonal load. The pipes need to be well anchored into the column-floor junctions.



In addition, the diagram illustrates some elements of an alternative construction design using stiffener columns cast after the masonry of the brick walls and elements to improve ventilation:

1) Wider support columns and footings, reducing the possibility of settlement.
2) Increased number of stirrups in columns and beams where maximum moments will occur. The floor beam is not thicker/heavier than the column. The columns are stiffer than the floor construction.
3) Diagonal bracing of the stilts, using either pre-cast reinforced concrete poles or heavy-duty galvanised pipes well anchored into the ground.
4) Stiffener columns, cast after masoning the brick walls, with short anchoring into the brick walls.
5) Thin upper tie-beams at the ceiling level through and over all the walls.
6) Thin upper tie-beams over the gable ends, incorporating the timber wall plate.
7) Wooden wall plate on the gable ends anchored into the concrete upper tie-beam.
8) Large windows and doors, allowing plenty of cross ventilation.
9) Upper ventilation vents located well under the roof overhang.
10) Lower ventilation vents located under windows; rain should not be allowed to enter.
11) Gable top ventilation openings of pre-cast decorative cement blocks that allow cross ventilation under the roof and above the suspended ceiling.
12) Lightweight floor construction that can absorb a little settlement.
13) Suspended ceiling of fibre-cement boards (asbestos-free).
14) Fibre-cement board internal walls instead of masoned walls, reducing the weight of the building as compared to cement block or brick masoned walls.

5.2 Building the Columns

The foundation columns continue structurally into the columns of the first floor. In one construction site (left photo below), the reinforcement bars stop about one meter above the floor level, while the second contractor (right photo below) has placed the complete vertical reinforcement as one piece. Although the later requires some temporary support, this design is better as it does not require overlapping of the reinforcement bars in the base of the columns above the floor, thus saving steel reinforcement.

For a smooth concrete reinforcement bar to work properly, the bar needs to be anchored over a length of minimal 50 times its diameter in the concrete before it can develop its planned strength. In the overlap section, additional stirrups need to be placed. For cold deformed bars, the minimal overlap is 40 times the diameter. In addition, both bar types need end-hooks.

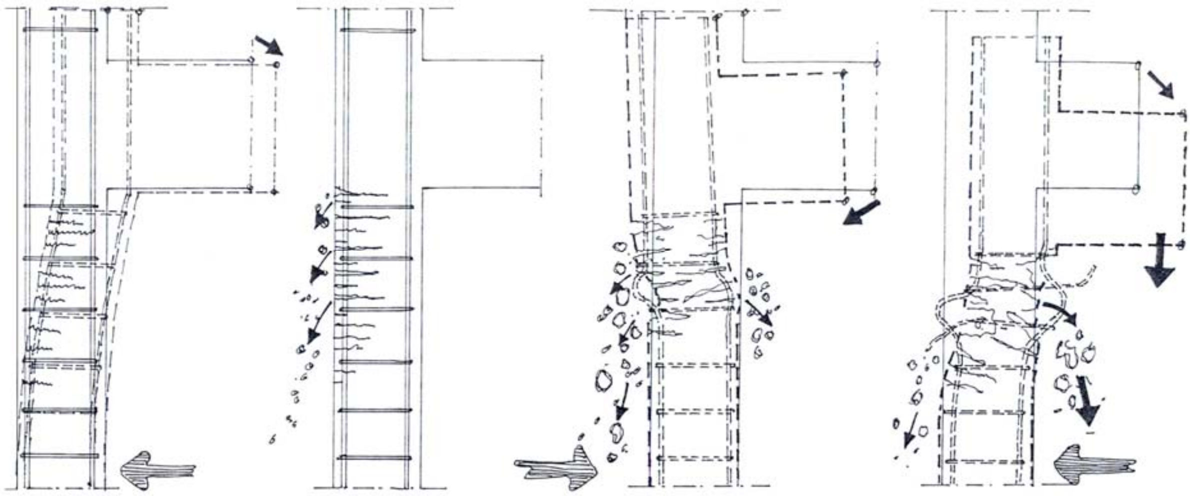
Recommendation
The reinforcement of the columns should be in one piece, where possible, to minimise overlaps.

5.3 Column Reinforcement Design

The ground floor of the house consists of a reinforced concrete floor with 30 cm high concrete ring beams. The walls will be made of brick masonry between the 20 cm x 20 cm columns and plastered. The floor, along with the walls, makes a very stiff box structure standing on the foundation columns. The foundation columns have moment-stiff connections with the floor beams. During an earthquake, the maximum moment will occur at this place and so it is essential to place sufficient stirrups just under the beam. If the maximum design force is exceeded during an earthquake, the concrete will crumble, but not fall out of a cage of stirrups just under the beam. When the columns remain standing, it gives the occupants time to escape from the house during a prolonged earthquake.

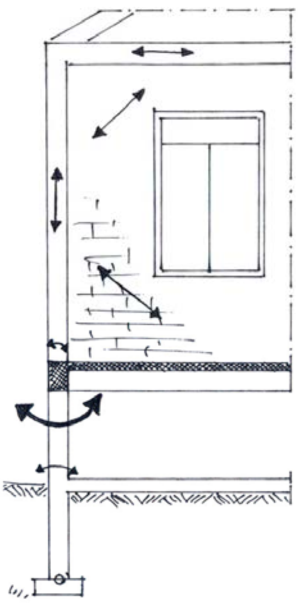
Typical Column Failure – No Stirrups

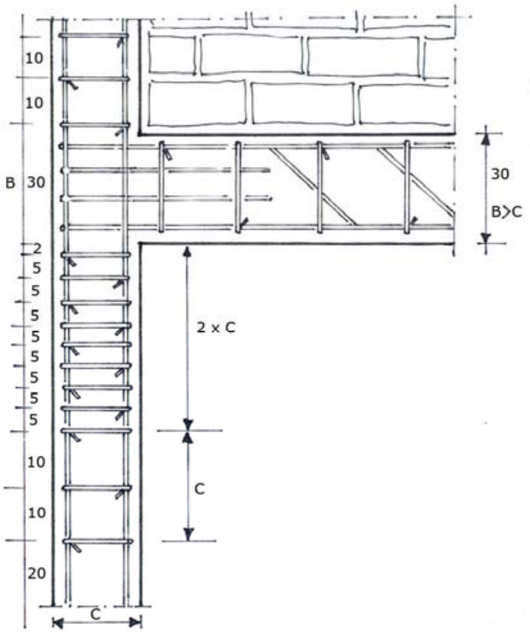
Observation on photo – page 12 (bottom right): At the vital maximum moment zone, there were insufficient stirrups. As a result, the concrete crumbled and fell out during an earthquake. The sketches below explain the process of failure during one shock. In reality, a series of shocks occur during an earthquake, continuing the described process and resulting in the column collapsing and with that bringing the house down.



Recommendation

Each column end should be reinforced with a cage of stirrups at its maximum moment zone to avoid broken concrete from falling out of the construction when earthquake forces exceed the design forces. This is especially the case when the floor beams are stronger than the columns. The column ends should therefore have 6 mm stirrups every 5 cm over a length of minimal 1.5 times the column width under the floor beam, followed by two stirrups 10 cm apart and then continuing with stirrups every 20 cm for the rest of the column.





The sketch on the left shows the forces that occur in the current structural design. Only the stilt column is subject to a strong bending moment, while the upper column and tie-beam only receive compression and stress forces when the infill wall remains intact. In such a case, the reinforcement pattern sketched on the right is recommended. Better still is when the floor beam is lighter or thinner than the column, shifting the possible failure area to the beam.

5.4 Design Strength of Columns

The columns were designed with six smooth bars of 12 mm and two bars of 10 mm, with a total section of 8.4 cm^2 or about 2% steel in relation to the concrete section (400 cm^2). Due to the unavailability of smooth bars, the contractor applied six cold deformed ribbed bars of 12 mm and two smooth bars of 10 mm. In combination with cold deformed ribbed steel, the smooth steel, having a lower strength and stiffness, becomes useless. In the above configuration, the smooth bars will only start to work after the cold deformed ribbed steel and the construction has already failed.

Recommendation
Never use two different types of steel reinforcement bars in the same force direction, such as low-strength smooth steel with high-strength cold deformed ribbed bars.

Recommendation
The approved technical designs should preferably be accompanied by the relevant calculations. When the specified steel types or diameters are unavailable due to external circumstances, such as may occur in an overstressed market (emergency reconstruction), the implementing organisation along with the contractor need to recalculate the design for the available reinforcement bar type. The recalculation of the reinforcement bars needs to be re-approved by the design office and local authorities.

5.5 Ring Beams

The ring beams form one entity with the concrete floor and create a stiff platform for the upper house. The reinforcement for these beams was being manufactured beam-by-beam and assembled in-situ above the formwork. After assembly, the bar-beam section was then lowered into the formwork.

Observation: The eight reinforcement bars in the beam are not going around the 90° corner into the other horizontal beam section, but instead end with hooks inside the column. The eight hooks in the column, coming from two directions, totally congest the space inside the column. When casting the column with concrete, air pockets will be created. Because of the inadequate length of the hooks, the junction will be far below the required structural strength. The situation is aggravated in two other corners because two additional bars were added.

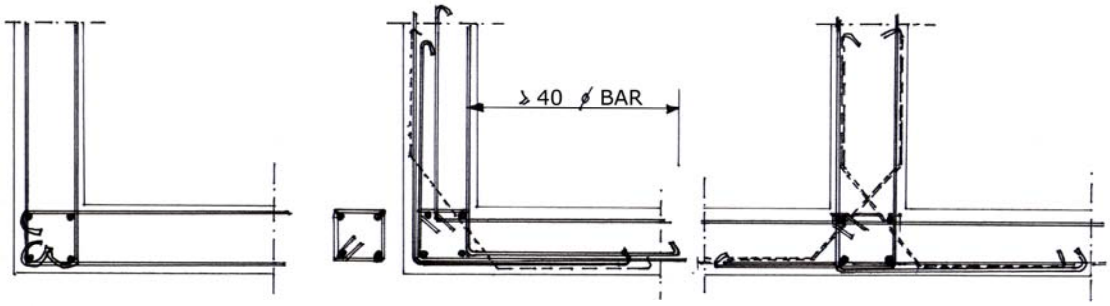
The Po Diamat house design has 13 support columns – nine columns under the main house and four under the front and rear side terraces. The four terrace columns and two other corner columns all have the above-mentioned anchoring failure of the beam-column junction. The result is that possibly only the seven central columns will be able to withstand an earthquake load. Recalculation of the strength of the central seven columns, having additional reinforcements, needs to be undertaken to determine if they are adequate to withstand an earthquake load. If the building is fitted with lightweight inside walls, this may be the case.

The strength of the beam-column junction depends on the continuity of the bars from one beam into the other and their adequate anchoring length in the concrete, not on hooks in the junction. The error in these junctions is based on the following issues:

- The design drawings were not specific enough in the reinforcement bar design.
- When the BRR recommended additional bars, the modified design was not reviewed.
- There were no calculations provided with the reinforcement design.
- The design drawings did not have a reinforcement bar cutting-folding schedule.
- The contractor does not have the required experience in reinforcement design.
- The site supervisor does not have the required experience in reinforcement design.

Recommendation

The reinforcement design of the ring beams should be detailed showing the reinforcement bars going around the corner, instead of ending with hooks inside the columns.



Left Sketch: Illustrates the applied reinforcement. In reality, four bars were applied in both the upper layer and bottom layer of the beam.

Middle Sketch: Illustrates the correct application of the beam reinforcements. These go through the column, around the corner and end in a hook, providing minimal a 40 bar diameter overlap. The possibility exists to add another diagonal bar (dotted line) depending on the force calculations. In the areas of the maximum moment, in the beam as well as in the column, additional stirrups should be placed with 5-6 cm spacing.

Right Sketch: Illustrates the same principle for a T-junction.

Recommendation

Detailed drawings of the ring beam reinforcement bars should be provided and a cutting-folding schedule made available for the ironworkers. The length, shape and quantity of bars need to be detailed for each reinforcement location. Making the reinforcement bar cutting-folding schedule is commonly the task of the architect or engineer providing the drawings.

BAR	NO.	DRAWING FLOOR CONSTRUCTION BEAM "A"	BAR	M'	KG
51	4	40 – 360 – 40, ϕ12 TOR	440	17.60	15.52
52	1	40 – 80 – 42 – 20 – 160 – 42 – 20 – 80 – 40, ϕ12 TOR	48	4.84	4.27
53	1	40 – 60 – 42 – 20 – 200 – 42 – 20 – 60 – 40, ϕ12 TOR	484	4.84	4.27
54	12	20 – 30 – 30 – 10 – 20, ϕ8, Stirrup Smooth	80	9.60	3.76
55	2	110 – 10 – 360 – 10 – 110, ϕ12 TOR	600	12.00	10.58

Sample Reinforcement Bar Cutting-Folding Schedule

5.6 Ring Beam – Column Stiffness

When excessive earthquake forces occur, the beams should fail first, allowing the columns to continue supporting the house. However, in the current Po Diamat design, the ring beams with the attached floor are stiffer than the stilt columns under the floor. The upper part of the building will behave as one stiff block, resulting in the columns failing first and thereby causing the building to collapse. If in the given design the column-beam construction had been well implemented (with reinforcement bars going around the corner), there would be no strength issue at all.

Recommendations

- *In an earthquake-resistant reinforced concrete design, the ring beams should be less stiff (and therefore less thick) than the width of the columns. In other words, the columns need to be relatively stronger than the connecting beams. The maximum moment of the ring beam is at the junction with the column; therefore, the beams should also have stirrups narrowly spaced at these maximum moment areas.*

- *In the event the design gets an overall review, it is suggested to make the floor beam lighter than the column.*

5.7 Floor

The 12 cm thick reinforced concrete floor with a plaster finish is a heavy construction, responsible for minimal 12 ton of the building's weight above the columns (= 30% of the mass of the building). These thin reinforced concrete floors are easily affected by the sea climate and the reinforcement iron will corrode if the concrete covering at the underside of the floor is not adequate. Such may be the case when concrete is hand mixed, water or sand with salt content is used, insufficient spacers are placed, insufficiently vibrated, etc.

Recommendation
Lightweight or pre-fabricated floor constructions should be considered when redesigning the coastal constructions.

5.8 Trusses

The gable ends of the house are bordered along their upper side with a heavy pre-constructed reinforced concrete beam instead of with a simple cast-on stiffener tie-beam. The current construction is unnecessarily heavy and expensive. Along the inside of these gable ends (front and rear of the house), a full wooden truss has been placed in order to nail the support beams ("gording") for the lightweight metallic roofing sheets. In the centre of the roof, a third truss is placed on the central wall. The wooden trusses are very well designed with adequate bolts and connector plates.

Recommendation
Only one central truss is required instead of three. Instead of the two gable end trusses, a plank with anchors can be pressed into the fresh concrete when making the stiffener tie-beam over the gable ends. This would save considerable money and work.

5.9 Reinforced Concrete Quality

The actual quality of reinforced concrete, and therefore the strength of the house, largely depends on good site supervision and workmanship by the building contractor. Even when the design is correct, but poorly executed, the construction will not stand up adequately in a large earthquake. This applies to the following aspects of reinforced concrete:

- Too many concentrated reinforcement bars; thereby not allowing the concrete to be cast properly in between and around the reinforcements.
- Nailing the formwork into fresh concrete of the columns and with that damaging the columns and allowing corrosion.
- Formwork that allows leakage of cement water; thereby causing aggregate pockets.

- Weak formwork (support) that may sag during casting; thereby deforming the design.
- Formwork with un-cast passages or ducts at maximum moment locations, weakening the construction.
- Leaving binding wire inside the formwork.
- Not having enough bar-to-formwork separators on the reinforcement.
- Using a corrosive mixture – sand, stone aggregate or water with salt content.
- Inadequate density of the concrete due to non-scaled grading of sand and aggregate, presence of clay or dirt in the sand, or excess of water in the mix.
- No qualified inspection of the reinforcement and formwork prior to the casting.
- No qualified supervision during the casting of the concrete.
- Casting concrete without first wetting the adjoining brickwork.
- Casting columns without priming the columns with cement-sand slurry.
- Casting fresh concrete from higher than one meter without funnel.
- Insufficient densification (vibration or compaction of the concrete during casting).
- Insufficient curing of the concrete after casting, especially the columns.

If the above items are not well supervised and implemented, corrosion of the reinforcement bars will self-destroy the concrete.

The photo above shows how reinforcement bars can just pull out of the concrete, demonstrating insufficient adherence to the concrete. This is often due to poor concrete quality, but sometimes can be caused by inappropriate steel design.

Recommendation
The reinforcement for reinforced concrete constructions should preferably:
- *Be no more than 1% of the concrete section, with maximum 2% for columns.*
- *Use cold deformed ribbed bars rather than smooth bars.*
- *Use the same strength type of bars in the same force direction.*
- *Use many small diameter bars rather than a few large diameter bars.*
- *Use plenty of stirrups in all maximum moment areas and overlaps.*
- *Use minimum overlap requirement (50 bar diameter for smooth and 40 bar diameter for cold deformed steel). Both types of bars having end hooks.*
- *Have detailed drawings with precise cutting-folding tables for all reinforcement bars.*
- *Have minimum amount of splices or overlaps.*
- *Be well separated from the outside of the concrete through bar-to-formwork separators.*
- *Be inspected before casting the concrete to verify compliance to drawings.*

6. SUMMARY

The two projects visited are in several ways representative of good progress with the tsunami reconstruction activities. In both projects, consultation with the communities has resulted in a consensus decision-making, even if in the case of Po Diamat relocation was advised. The observations made are not exclusive to Cordia Medan projects. The same issues (problems) are commonly found in the design and reinforced concrete work of many of the reconstruction projects in the region.

The Trienggadeng project, now in its final stage of completion, conforms to the local government (BRR) standards and provides in most cases a more spacious and better quality accommodation for the tsunami victims than their previous dwellings. The design of the houses is ground-floor-only and with the applied reinforcement reasonably earthquake resistant. The houses are located in a high tsunami-risk area and the design correctly applies the proper reinforcement method, i.e. the walls are <u>not</u> anchored into the columns. Some improvements can be made with regard to site development, such as an elevated community building that can act as a safe haven in the event of another large tsunami.

Po Diamat is a rather unique project as it is one of the few tsunami reconstruction projects with the permanent houses elevated to avoid future flooding. These houses are also adequately earthquake resistant, partly because the steel reinforcement is over-dimensioned in all columns and beams. The added reinforcement makes the central seven columns stronger, but on the other hand, it makes the six corner columns weaker.

Also in this settlement, the realisation of a higher elevated building will provide refuge for escaping another tsunami, provided an advance warning system is established. Such a communal building should have easy access and an increased column height.

<u>Learning for the Future</u>
The recommendations focus on improving the concrete reinforcement and additional detailing of the reinforcement drawings for easy cutting and assembly on site to reduce possible mistakes. The recommendations will not only improve the overall performance of the construction during a large earthquake, and thereby increase the safety of the beneficiaries, but may also lead to cost savings in terms of labour and material (steel, concrete and timber).

Adjusting the design to conform to some recommendations may have a large impact on the safety of the beneficiaries or strength of the house when disaster strikes. Therefore I consider the following recommendations worthy of implementation in the two projects:

Trienggadeng:

- Design an elevated community building with easy access and ensure no fences or constructions are built between the houses.
- Ensure the kitchen extension is properly attached to the building.

Po Diamat:

- <u>Urgently</u> review the reinforcement of the beam connections to the columns, as these are faulty and actually weaken the most critical point in the stilt columns.
- Add the required <u>stirrups</u> in the upper part of the stilt column connection.
- Reduce the overall building mass by making the internal walls of lightweight material.
- Increase the ventilation vents and make them under the windows.
- Minimise the upper tie-beams and cast the wall-plate in the gable tie-beam.
- Design an elevated community building with easy access and ensure no fences or constructions are built between the houses.

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