

ALTERNATIVE BUILDING SYSTEM OF A⁷BS[®] CONCRETE THIN PLATE WITH PERMANENT CAVITY FORMPANELS- A GREEN BUILDING TECHNOLOGY

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ABSTRACT

Abstract Subject: Innovative and Affordable Alternative Building System of Concrete Thin Plate with permanent formpanels for Existing Building Retrofit and New Building Structures

Innovative, resilient, affordable, safe, energy-efficient, durable, sustainable, and simple to construct are key features of the construction industry's on-going search for building products, system and methodology that will result to building better structures and consequently better communities. Aside from the need for resilient structures in addressing natural disasters and compliance to building regulations, there is also the need for sustainably-efficient products, systems and methodologies that will warrant the achievement of three major objectives, namely:

1. Achieving higher or better ratings in durability, efficiency and sustainability,
2. Achieving the above many if not all features above at same time but build quicker
3. Achieving the features but affordable

This paper and technology presentation aims to provide an alternative building system called A⁷BS[®].

The A⁷BS[®] alternative building system work on the common, economical, durable and workable material called concrete. The research did not target the concrete material in detail, nor its design mixes and its concrete placement. The research and development was focused on the plate or shell section of the concrete technology that utilises the inherent structural strength of plate wall and slab/roof plate.

The research also focused on economical form panels that are developed to be permanent instead of being removed. This feature provides enhanced tensile strength, building regulation compliance of insulations and barriers as well as ready frame for cladding. The benefits of formpanel pre-fabrication for site installation and on-site concreting are quicker and safer construction methodology, lesser waste material, lesser skilled labour and less special tools and equipment for sustainable development

The A⁷BS[®] alternative building system can continually improve in order to achieve the objectives of better structures, improved building performance, affordable and better communities.

KEYWORDS:

High-resiliency; ready compliance; simpler-safer construction; energy-efficiency; affordability

INTRODUCTION

A⁷BS[®] alternative building system was developed more than two decades ago using the plate theory section of the concrete structures such as the slab plate or roof plate and wall plate, rather than the popular skeletal framing of beams and columns. Concrete plates of walls and floor slabs or roof plates in building structures create a box shell. George Winter and Arthur H Nilson on their book- Design of Concrete Structures provide technical information on the ACI 318 namely Section 4.12 Deep Beam p. 185 section 9.35 Shear Walls and section 9.38 Folded Plates, McGraw Hill Inc First Year of Publication, 1980 Reference [2].

A box shell structure provides resilient structure where normal walls act as load bearing elements and lateral resisting elements against natural forces (like earthquake, flash flood or tsunami). The concrete floor slab and/or roof plates act as a structure load platform, load transfer and load distributing element for the walls. Such load distributing effect and with concrete cast-in-situ system provide thinner wall elements per concrete standard provision but possessed the high benefits of strength for a resilient structure.

A cast-in-situ and monolithic concrete box shell structure uses simple wall-floor or wall-roof plate simple construction plate connection, and such provides a sealed structure. Sealed structure system gives improved energy efficiency rating of the building structure. Add to this sealed structure condition the permanent formpanels.

A⁷BS[®] alternative building system's concrete cast-in-situ methodology is made more efficient with its permanent cavity form panels (A⁷ formpanel). This formpanels research development from the 1991 three (3) dimensional space frame with recycled plastic form lining to removable metal form of 2002 and then to the 2010 permanent cavity ribbed formpanels improved its features for sustainability and green building technology. Concrete is a common building material and cheap, but requires the typical removable formwork that makes the material expensive. Providing a permanent metal cavity formpanel gives added tensile lining for walls against out of plane lateral forces (earthquake and flash flooding) and binding effect of brittle failure of concrete. The load bearing and later resisting wall element (shear walls) can be and must be designed as deep thin beams restraint by floor slabs and/or roof plate, minimised the requirement for expensive foundation system.

The A⁷ formpanels as a permanent lining are not only designed for the normal concreting of 3-5 meter high walls and designed floor slab or roof plate but also designed for building compliance requirement on insulation such as fire, thermal, noise barrier, damp barrier and insect-rodent barrier. Its insulation system was based on the heat conservation and transfer under the science of entropy. Of the different nomination of material the galvanized metal sheet roll formed to form ribs create also a cavity that provides space for services run (electrical, communication, water line). The cavity form panel with its simple fastening system provides ready battens or studs for any cladding fixing including stone or brick masonry.

The cavity formpanels that are pre-engineered, pre-manufactured, mass produced and factory-assembled wall-slab formwork system and ready for site installation provide a faster methodology of construction. This method minimize the cost on the use of on-site power tools, dependency on high skilled labour, down time due to weather related delay and higher safety environment on site. The formpanel fixing after concreting can provided next day ready support for scaffolding works for the next work stage or upper level works. It minimises wastage in construction materials and minimise cost of on-site works, skilled manpower and site-work management.

Thus, this international patent pending and 29-year research and development of concrete thin plate with permanent formpanels provides a complete structural fabric with building compliance, higher

resiliency against natural disaster and fire related disaster, plus simpler construction methodology, making this a sustainable green building system and affordable.

THE CONVENTIONAL SYSTEM AND THE CONCRETE THIN PLATE WITH FORMPANELS

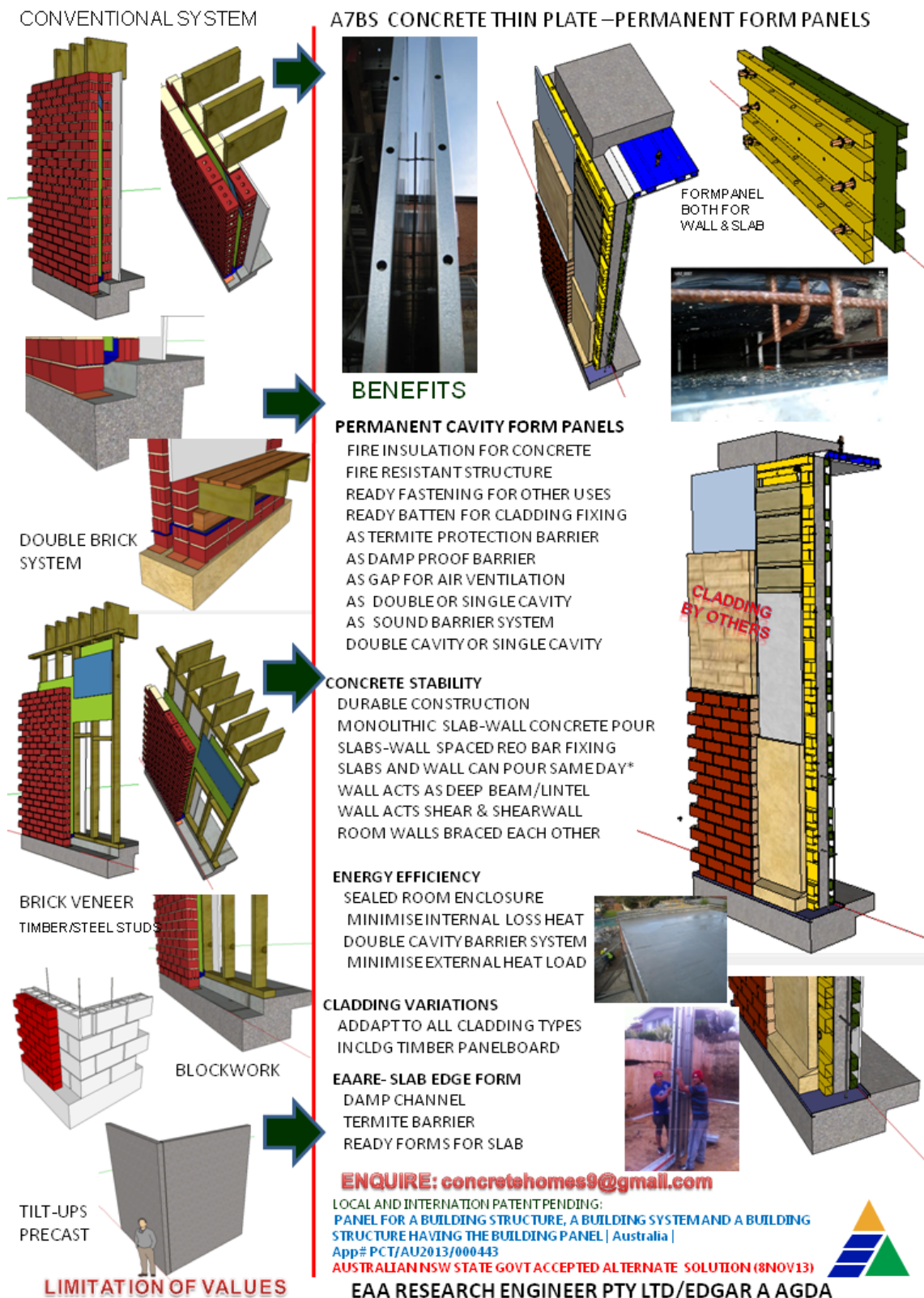
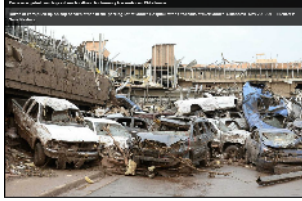


Illustration no 2: comparison of alternative building system to known conventional system

The above illustrations show the popular and conventional construction systems of brick veneer, double brick or brick or stone masonry, pre-cast or tilt up system of construction. These, among other systems like steel frame, had been used extensively for centuries, however the current natural disasters, the demand for energy efficiency, and better performance and affordability require a continuing search for alternative solutions or building systems.

Typical natural disasters affectation



Tornado/cyclone



House/bush fires



Earthquake/soil movement



Tsunami/flash flood

Construction issues (durability, site management, quality, services)



Site and Waste issues



Services runs

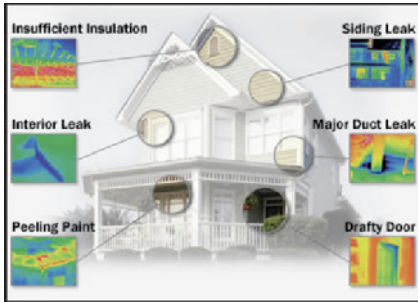


Workmanship

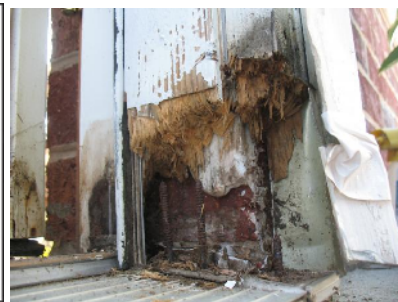


Quality & Strength issues

Energy, Maintenance, Durable but Costly construction



House energy and sound leaks



Damp, termites, rotten element



Removal formwork system/cost

The above illustrations are some of the challenges to the existing conventional construction system that require continuous research and improvement. These issues include:

- Building performance
- Users' perceptions of sustainable buildings in terms of their environmental and operational performance and their influence on health and productivity
- User performance benchmarks
- Low energy design and operation of commercial and institutional buildings
- Internal environments of buildings – thermal, air quality, acoustic and lighting conditions in practice
- Sustainable and regenerative systems in building design and retrofit

CONCRETE THIN PLATE W/ A7FORMPANELS

A7BS ALTERNATIVE BUILDING SYSTEM

8 NOV 2013 AUSTRALIAN NSW STATE ACCEPTED ALTERNATE SOLUTION

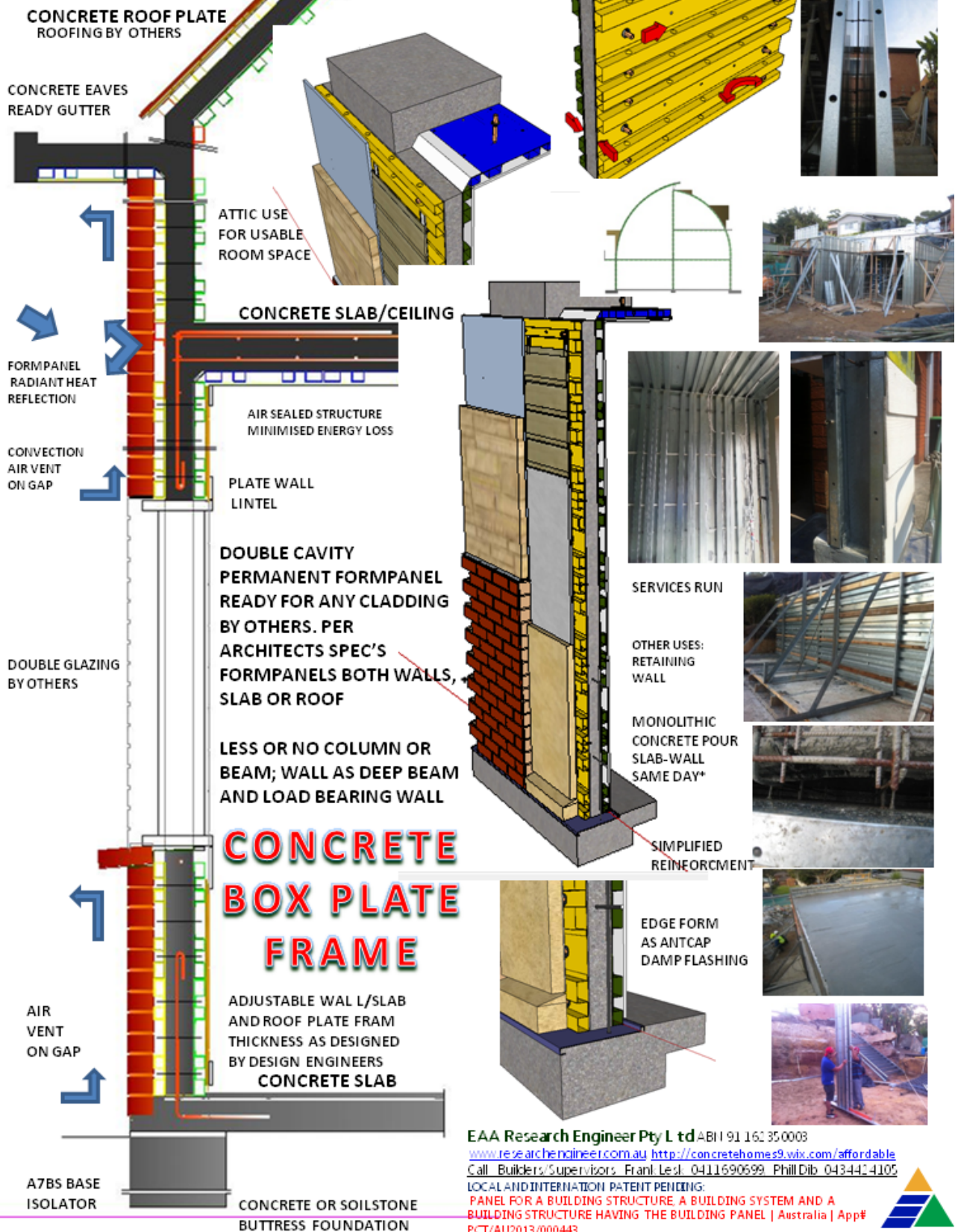


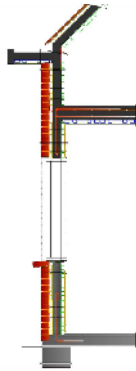
Illustration No 1: Concrete Thin plate with permanent form panels' description

CONCRETE THIN PLATE SYSTEM WITH PERMANENT FORMPANELS

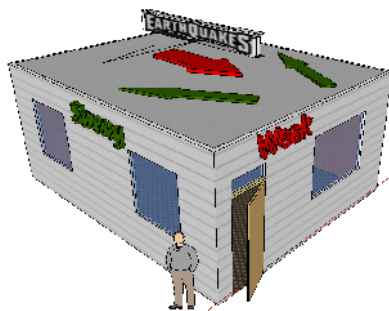
1. Better Performance Resilient structure

Concrete Thin Plate

Concrete Plate structure deals on wall and slab or roof plate rather than typical concrete columns and beams. In concrete plate theory the walls can act a deep beam as well as load bearing wall. When wall are fixed and monolithically connected with upper and level concrete slab or plates like roof or fly slab, the deep beam wall had a greater flexural strength out of an inverted L-shape beam or inverted T shape beam. This provides better wall performance structurally. Such condition of better structural performance will mean slender wall thickness per code standard provision and minimal size of foundation.



Deep wall L and T beam



Box Type, load transfer

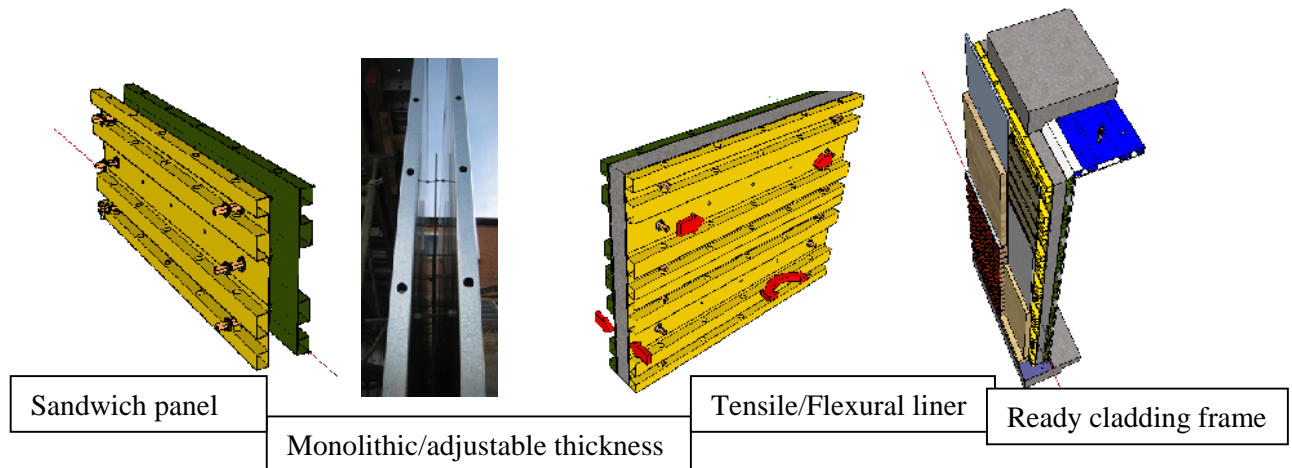


Bunker type concrete structure

The simple monolithic plate connection using cog bar reinforcement between the wall and slab or roof plate provide a box type concrete structure. Weak walls due to out-of-plane forces (like in earthquake) can be supported or restraint by the floor slabs and provides lateral load transfer to strong walls. Opposite walls or return wall provide bracing element to each other. Strong wall acts as shear walls. Making the walls performs as shear provides better structure performance during natural disaster. Concrete shear wall structures that was developed since the 1930's is one of the building type that have low probability to be earthquake prone (SeSoc Journal April 2013, p.44 fig 1 Reference [3])

The author provided a list of structural strength values of an example of a 100mm wall acting as both load bearing and shear strength capacity in a technical paper submitted and publish in a *Journal of the New Zealand Structural Engineering Society*, Volume 27 pages 62 to 72 titled - A⁷BS"Concrete Thin Plate" –alternative shear wall and load transferring plate element in existing building structure retrofit and new structures-Reference [1]. Example 1 meter of 100mm building wall had approximately 12 ton capacity strength against earthquake force.

Permanent Form panels



Concrete as a material is common, widely available and cheap. However, to construct and benefit from the use of plate structure requires a built up formwork and related propping with scaffolding system. The typical standardize formwork system is a timber formwork from form plywood and equally space laminated timber batten ribs. This removable formwork makes the concrete costly and such spent cost does not provide other benefits except serving its purpose as concrete formwork.

The A⁷BS®'s A⁷ formpanel is a permanent formwork that is formed from metal sheets by roll forming. Galvanized metal formpanels is highly recommended as economical, widely available and strong material. Rolled from wide coil sheet to form batten ribs, it was designed to allow wall concrete casting to wall height of 3 to 5 meters due to bracing angles.

The A⁷ **formpanels system** had a number of combination type and accessories to provide a completely sealed formwork ready for concreting.

After concreting, the permanent formpanel had a number of benefits instead of spent formwork cost, namely:

Structural:

- Sandwich concrete wall by the formpanel providing a binding and tensile strength
- A metal panel tie and tie down of the wall against movement cracks
- Walls as bracing and buttressing wall against disaster forces

Building Code compliance:

- Fire insulation as per Australian Standard AS3600 (Concrete Structures) Section 5.7.5 "added fire insulation".
- Noise Barrier
- Air vent insulation
- Energy efficiency out of sealed box system
- Termite barrier
- Damp proof barriers
- Thermal Insulation

2. **Insulation, Barrier and Energy Efficient system of A⁷BS® Alternative Building System**

Fire Insulation

AS3600 Table 5.7.4 identifies the fire rating values of concrete wall by the concrete cover thickness. Section 5.10.1.2 and Section 5.7.5 indicates increasing fire resistance by insulating material. The formpanels provide cavity metal form lining protection/insulation of the concrete against fire. Concrete and metal are fire resistant. The resulting fire rating values for a 100mm thick wall with minimum code reinforcement at wall centre plus the formpanel will provide more than 4 hours fire rating. The formpanel will provide to the fire fuel to any cladding material.

Noise Barrier

A monolithic concrete box system provides a less if not seamless air leaks for noise except for air leaks in doors and windows openings. A bunker type concrete structure with rib formpanel has high insulation against noise or sound interference.

Air gap insulation/ Air ventilation

The built up wall system of concrete plate with permanent formpanel and internal-external cladding provides single or double cavity or air gap for heated air to be vent out by way of air exchange under the science laws of entropy.

Termite/Insect and Rodent Barrier

The metal formpanels on walls operate like ant-caps preventing termite and other insect migration.

Note: If the system will be used in warehouse food storages, having internal and external permanent formpanels, it will provide the following benefits:

- a sealed structure against rodent and insect intrusion
- metal material provides deterrence against their habitation
- the internal gap provide access for dryer or heat filaments for insect deterrence

Damp proof barrier

There are five layers of defence that provide higher damp barrier with the system, namely:

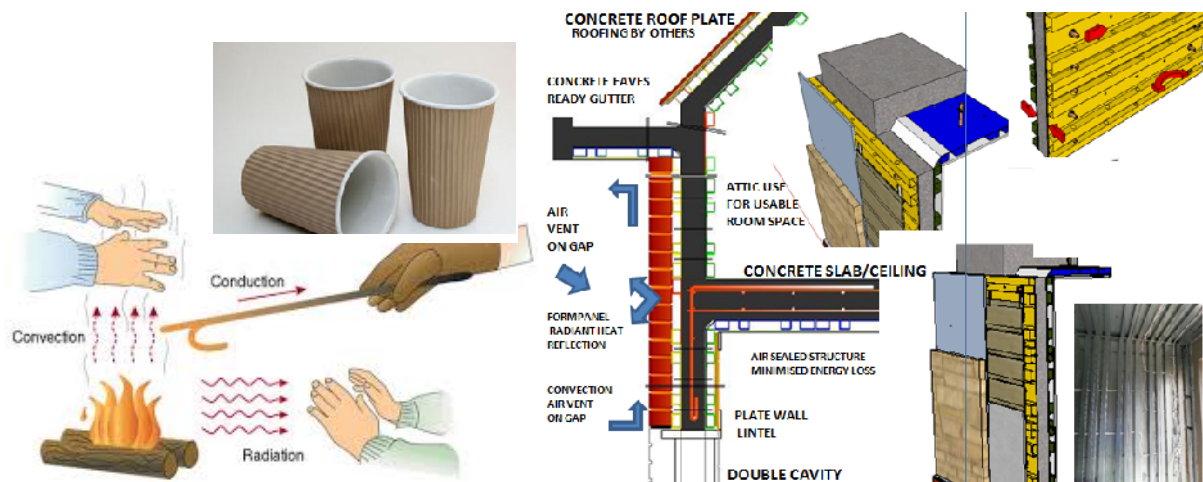
- External cladding system
- The External form panels (if decided to be permanent)
- The ventilated external cavity or air gap that provide air drying
- The monolithic solid concrete wall and joints with floor slab or roof plate
- The internal form panel provide a gap separation of the concrete wall to the internal cladding preventing damp or wet condition

Energy efficiency of a sealed box shell system with permanent formpanels

The concrete thin plate with permanent formpanels provides added thermal efficiency based on the following inherent built up structure system:

- The monolithic concrete box shell minimises if not eliminates air leaks between internal and external air difference
- Furthermore, the metal form panels on one or both side of the wall provides added sealing against air leaks
- Reflective metal form panels on one or either side of the wall provides conservation of heating or cooling energy

Thermal insulation by laws of science of entropy



The concrete thin plate with formpanel aid to thermal insulation is based on the following:

External heat entry (during summer)

- Any external cladding provide first barrier against external heat by reflection, heat dissipation by air exchange cooling
- Heated cladding conduct heat transfer by limited are of contact (e.g. fixing screws) of the cladding to the formpanels. Less contact results in reduce heat conduction.
- Galvanized metal forms reflects back percentage of heat that penetrates the cladding
- The air exchange or air venting in gap reduces the heated temperature by way of laws of entropy in science of heat transfer. This can be simply explained by the corrugated coffee cup, where a person does not burn it hand holding the cup though 100 deg boiling hot water in the cup. The greater the temperature difference means the rate of air exchange. Thus heat conduction in the gap easily cools down. A 40 deg hot summer air will have a 50-60% or more heat reduction, making a normal room temp.
- Though metal is a heat conductor, but air convection provides heat transfer reduction

Internal heat conservation (during winter) or internal room cooling conservation

- The sealed box shell structure has high conservation of heat energy or cooling temp
- The internal formpanel provide added sealing against air leaks
- The internal formpanel reflect back the heat energy of heated room temperature

3. Construction, Management, Services, Safety benefits of pre-Fabrication of Formpanels Mechanical, Electrical, and HVAC services runs

The gap for the external and internal formpanel can provide pipe run for the following:

- Electrical runs in the air gap means no interfere to concrete structure
- Communication cable and auxiliary wirings runs separation for easy maintenance
- Mechanical pipe for fresh air intake runs in the formpanel air gaps (walls & ceiling)
- Copper pipe water runs in the internal and external gaps
- Ready fixing for mechanical ducting and HVAC services

Construction Management, Safety and Time/Cost Saving

- Pre Manufactured/Pre engineered and Pre assembled Modular Formworks for easy construction methodology
- Pre Fabrication means less on-site power tool use and less skilled labouring
- Less work on site means less hazard work and safer construction site
- Ready support structure to upper level work scaffold and propping
- Less on site works means less construction waste and therefore economical
- Ready framings for cladding system
- The above benefits provide less construction time, safer and economical construction
- The above resiliency and economic benefits makes a green building technology

Simplified formpanel fixing and its use for services and fixture fixing

Formpanel simple fixing system provides other uses after concreting

- Stone masonry or brick cladding fixing (alternative to brick or masonry ties)
- Wall and ceiling shelving and appliance fixing
- Other fixing requirement and non load bearing partition fixing requirements

4. Concrete Thin Plate and Formpanels in Retrofitting of existing buildings

Most of the existing houses built more than 30 years ago, no longer comply with the current standards in terms of resiliency, energy efficiency, sustainability and other green building initiatives. A⁷BS[®] provides solution for retrofitting as well as compliance to current regulations on the following items as shown in the succeeding figures:

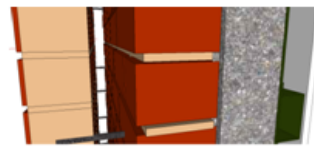
- Provide a concrete thin plate application with formpanel that binds all stone masonry or brick materials into one supporting plate element including parapets and chimneys
- Provide new but better brick or masonry ties of the old wall to the new concrete plate
- Provide the benefit of shear wall system to the existing building wall as identified in item no. 1
- Provide tensile lining to the wall against out of plane forces similar to item 1
- Provide all the regulation requirement related insulations to the existing building as identified in items 2, and 3
- Provide a new foundation support designed to current assessment of the soil and site conditions
- Provide compliance of retrofitting in accordance to the current site risk assessment

RETROFITTING by CONCRETE THIN PLATE WITH PERMANENT FORMPANELS

UnReinforced Masonry BUILDINGS

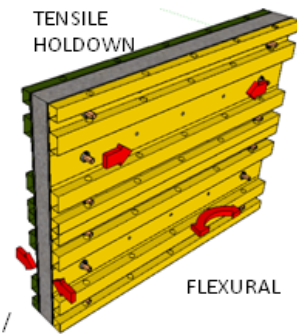


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THREADER ROD
INSERTS

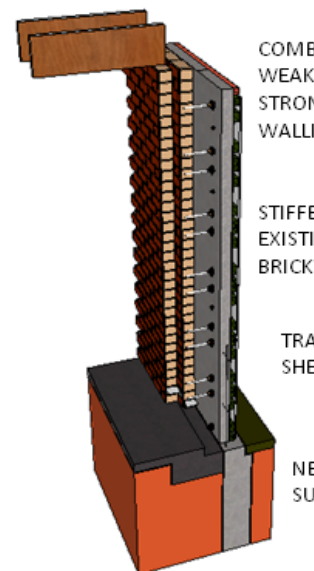
CONCRETE
GRIP



TENSILE
HOLDOWN

FLEXURAL

BINDING/
SANDWICH

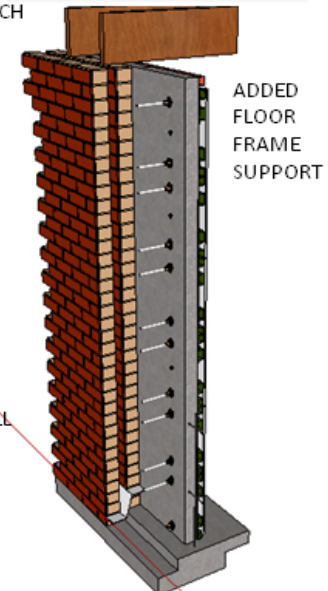


COMBINED
WEAK AND
STRONG
WALLING

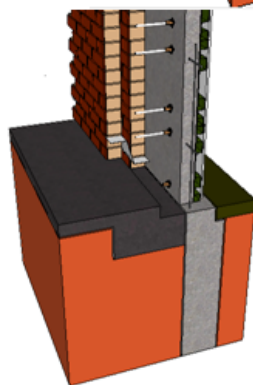
STIFFENS
EXISTING
BRICKWAL

TRANSFER
SHEAR WALL

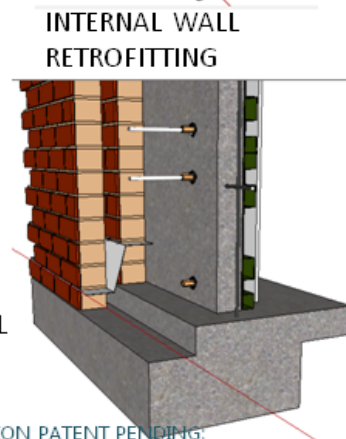
NEW
SUPPORT



ADDED
FLOOR
FRAME
SUPPORT



EXTERNAL WALL
RETROFITTING



INTERNAL WALL
RETROFITTING

LOCAL AND INTERNATIONAL PATENT PENDING:
PANEL FOR A BUILDING STRUCTURE, A BUILDING
SYSTEM AND A BUILDING STRUCTURE HAVING THE
BUILDING PANEL | Australia | App# PCT/AU2013/000443

CONCLUSION

A⁷BS[®] alternative building system uses the most common, widely available and cheap material which is concrete. Making the conventional removable formwork to a permanent cavity form panel, not only saves the expensive labour and material cost of making concrete structures and minimise waste material but also provide extensive benefits such as compliance to regulations (fire and thermal insulations, sound and damp barrier) and ready fixing battens for any recommended cladding.

A⁷BS[®] alternative building system utilises the concrete plate theory like walls and slab for its structural building fabric more than the typical beams and columns. Load bearing wall plates act as deep L type or T type beams with the floor slabs or roof plate, minimising concrete volume as thinner section and minimize foundation structure. Walls act as bracing to each other and restraints at the end of the floor slab or roof plate provide a box plate shell that gives a high resiliency against natural disasters like earthquakes.

A⁷BS[®] s' A⁷ Formpanels are designed to be pre-engineered, pre-fabricated, and pre-assembled to full wall height with or without floor/roof slab panels using temporary bracing angles. The assembled panel sets are to be shipped and craned on site for installation. Propping and scaffolding works are set for finalising the reinforcement for slabs and joints. Cast-in-situ concreting can be for walls or wall and slab on the same day depending on conditions. The construction process is simpler and quicker compared to the conventional methodology sequence of skeletal beam and columns prior to walls.

The advantages and benefits make A⁷BS[®] alternative building system a green building technology.

A⁷BS[®] alternative building system is an innovative invention. The green building technology has a current international patent (pending) documentation from May 2013 and a November 2013 New South Wales state government approval as accepted alternate solution under the Building Code of Australia (BCA) Vol 2, Section 1.0.5 (b) and 1.0.8, and Section 3.3. The research was started with the objectives of finding an economical and resilient building system. From thereon, it has been modified and refined to respond to current trends in sustainability and green building industry move.

REFERENCES

- [1] Agda Edgar A, A⁷BS“Concrete Thin Plate” –alternative shear wall and load transferring plate element in existing building structure retrofit and new structures , *Journal of the New Zealand Structural Engineering Society*, Volume 27 pages 62 to 72
- [2] George Winter and Arthur H Nilson Design of Concrete Structures section 9.35 Shear Walls and section 9.38 Folded Plates, McGraw Hill Inc First Year of Publication, 1980
- [3] John Hare 24 February, 2013. Earthquake Prone Buildings-Discussion Paper, *Journal of the New Zealand Structural Engineering Society*, Vol 25 No 1 April 2013 Appendix A page 44; Auckland: SESOC
- [4] American Concrete Institute (ACI-318) section 11.8 Concrete Shells
- [5] Building Code of Australia Volume 2, Table 5.7.4 and Section 5.7.5 Fire Insulation; and SECTION 1.0.5 (b) and 1.0.8, and BCA Vol. 2 Section 3.3 The performance nature of this document provides flexibility and allows the use of alternative construction methods even though they **may not be specifically described** in an acceptable construction manual or as acceptable construction practice. Alternative Solutions allow you to do things differently from the Deemed to Satisfy (DTS)