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From Vision to Reality: Modular Housing System for the Creation of Earthquake-Proof Living Space

Customer enquiries from countries with rapidly growing populations and an enormous need for high-quality, affordable living space have prompted Ratec and Reymann Technik from Hockenheim to develop an independent modular housing concept based on their upcrete® technology. The idea then became an impressive housing construction project in Peru that sets standards for similar projects in the future.

The customer, Llaxta, is a construction development company based in Lima, Peru which approached the corporate group in Hockenheim for its most recent project in Ica approximately 300 km from Lima.

The plan is to create "Las Piedras de Buenavista" in an area situated approximately 10 km from the town centre of Ica. A safe, modern housing development with its own shopping mall, boulevard, lagoon, playing fields, skate park, school, church and 91,000 m² of open green spaces which will offer a high standard of living at affordable prices. Llaxta was fortunate to secure the prestigious Peruvian architect Mario Lara for the design of the overall housing development.

The requirements of the Peruvian customer are demanding: the aim is to create 3,600 houses each with 3 rooms, 70 m² living space on two floors its own patio and garden, on a site covering 1,000,000 m² within a period of only 60 months. The houses should be both earthquake-proof and also storm-proof and have a pleasant room climate. Other requirements are: excellent surface qualities, thin-walled cross-sections

and minimization of the materials used. To handle the current huge demand for living space as quickly as possible and thus to ensure the project's success, the production system must guarantee short construction times, cost-efficiency and high quality. All those involved considered that the modular construction method met all these requirements, particularly in conjunction with the upcrete technology.

Not a new topic – but one turned completely upside down

The basic idea is the monolithic fabrication of a room module which combines the supporting walls, floor and beams with electrical and sanitary installations and manufactures it "in one pour". That leaves only the roof, partition walls, stairs and balconies, as appropriate. They are concreted in separate formwork and can be installed on the building site. This approach is not entirely new. The Reymann Group has been significantly involved in the development of new fabrication and production methods for the efficient manufacture of buildings using modular construction systems for over a decade. By building prototypes and con-

ducting various experiments, the company in Hockenheim has tested a wide range of different methods and concrete mixes, enhanced its formwork for modules, refined production processes and logistical aspects and in doing so has created a complete system that can now be used for the production of modular houses.

It was clear after the initial discussions between Llaxta and Ratec/Reymann Technik at the end of 2009 that the Group from Hockenheim, with its expertise gained from plant design, room module formwork, high-precision formwork technology and the self-developed upcrete process, offers precisely the solutions required to implement a housing construction project of this size and with the necessary element quality. The joint development work, design and planning required to achieve product and production clarity took a little more than 2 years. In the end, Reymann Technik took over implementation of the turnkey plant as the general contractor. In addition to formwork and Ratec's pump technology, Reymann Technik planned and delivered all the equipment with mixing plant, concrete laboratory, bucket track, reinforce-



Fig. 1: The 1,000,000 m² site will become home for more than 10,000 people within a mere 60 months.



Fig. 2: Less than 48 h from start to finished house



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Fig. 3: Building shell of the factory hall which was also designed by Reymann Technik jointly with the customer.



Fig. 4: The factory in Ica. The factory building will become the housing development's new shopping mall and community centre when construction is complete.

ment technology, transport systems, cranes and all the construction site logistics for the customer.

From the initial idea down to the last part – 100% made in Hockenheim

From the first CAD drawing down to the smallest parts, all moulds and pumps were manufactured in Hockenheim, in total:

- 3 room modules $3 \times 6 \times 3$ m ($w \times l \times h$)
- 1 battery mould with 6 pockets 8×3 m
- 2 stair moulds
- 2 balcony moulds
- 2 PumpCars based on UPP 100

The complete plant with a total weight of over 500 tons was shipped to South America by sea in 34 containers. Reymann Technik also designed the production hall ($25 \times 12 \times 110$ m) in steel construction joint-

ly with the customer. After the houses have been completed, this hall will not be demolished but will then accommodate the new housing development's community centre and shopping mall. Production, installation and commissioning of the plant was completed within 10 months in the spring of 2013.

Less than 48 h from start to finished house

In the meantime, two complete houses are produced in Ica per day, each consisting of 3 room modules, 6 partition and exposed walls, 1 staircase, 1 balcony and 2 roofs. This output is based on the upcrete technology. Upcrete – "concreting upwards" – is a process developed by Ratec and Reymann Technik and involves using a rotor-type pump to pressure fill a mould from below with self-compacting concrete (SCC). In

conjunction with the pressure-resistant moulds specially designed for the process, upcrete enables in situ production even with complex geometries and makes subsequent mechanical compacting superfluous. The concrete is completely and evenly distributed inside the mould. This ensures the all-round good surface quality, edge sharpness and dimensional accuracy on the module desired by the customer and cannot be achieved in this form with any other process.

With conventional processes, the room module is concreted in the upside down installation position and has to be turned after curing. In addition to an elaborate and expensive turning mechanism, this also requires a great deal of space. Another disadvantage arising due to turning into the installation position are the high forces that occur which can lead to cracks in the con-

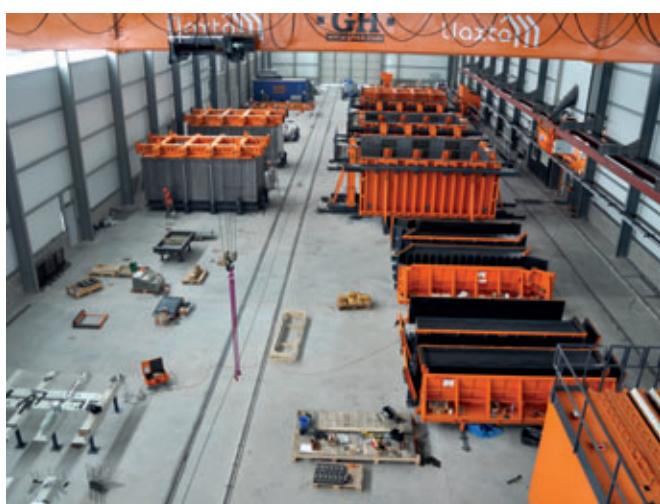


Fig. 5: Production with 3 module moulds, roof and stair moulds plus battery



Fig. 6: The opened module formwork. Recesses for windows and doors are attached to the outer formwork.



Fig. 7: The core prepared with reinforcement, internals, water and electricity connections is inserted into the module formwork.

crete components and, associated with this, the high degree of curing which the module must have achieved before it can be processed further or transported.

This is where upcrete saves significantly on space and time. The room module formwork developed by Ratec consists of an outer mould and a mould core which is "shrunk" for removal of the mould and lifted out. The overall width of the core can be reduced after curing of the concrete by 4 cm on the walls and 2 cm at the corners.

All preparations, such as reinforcement, fixing of internals, water pipes and electricity connections, are carried out on the module core which is then inserted into the outer formwork and fixed in place. Via a concrete filling connection, a UPP 100 (upcrete PumpCar) is used to fill the formwork from below with self-compacting concrete which is transported from the mixing plant to the pump by way of a bucket track. The specially designed concrete inlet enables the distribution of concrete with a smooth finish on the pre-fabricated component.

The room module can be removed from the mould after 7 – 9 hours when the lifting strength has been reached. Side formwork, inner



Fig. 8: Connection of the pump to the formwork



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Flexibility and durability in perfect harmony

e.g. SAS, the shoring system for the manufacture of facades, sandwich walls, solid walls and floor systems, is available in lengths of up to 8000mm and heights from 60mm to 400mm. The system is used in both manual handling and robot operation. The economic aspects are: reduced consumption of shoring timber, reduced shoring and demoulding times, simplified cleaning and improved quality of the final product. Simple, flexible, fast, safe and efficient positioning is ensured by the switchable RATEC automatic system. RATEC magnetic components with adhesive forces from 450kg to 2100kg are used here depending on requirements.

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Fig. 9: The outer formwork can be opened after removing the "shrink core".

core and cover can be used immediately for concreting the next room module which saves valuable production and working time and also prevents downtime. The modules are finished directly in the plant by painting, installing plumbing and fitting doors and windows. After completion, the

room module is transported to the construction site for installation. Interior walls, stairs, balcony and roof are manufactured in parallel and the foundations are prefabricated on the construction site at the same time. Complete final assembly of the house thus takes place "just in time", assisted by well



Fig. 10: Sharp edges and smooth formwork surfaces on all sides

thought-out, intelligent production processes and by optimising the site logistics to the production capacity. Reymann group technology solutions and Llaxta's industrialization process in the housing sector have made this production system possible.



Fig. 11: The room module is transported for further processing by means of special lifting beams and a 12.5 t crane.



Fig. 12: Roofs, balconies and stairs are produced in parallel in separate moulds



Fig. 13: The room modules are finished while still at the plant

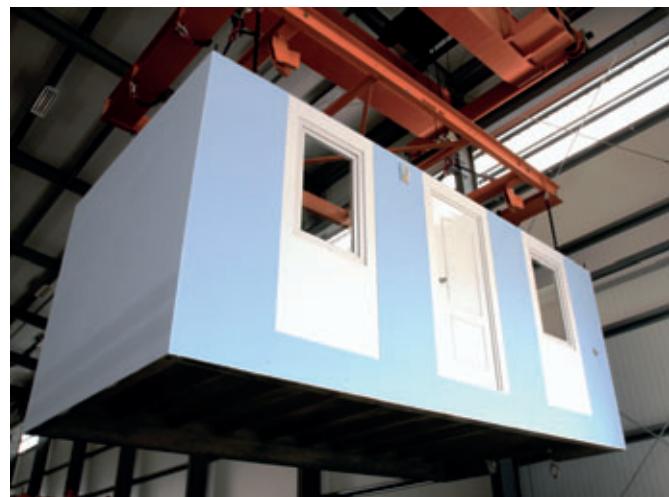


Fig. 14: The finished module is transported to the construction site ready for installation.

Modular construction for earthquake safety is clearly an advantage

One of the customer's main reasons for deciding on the modular construction method was to guarantee earthquake safety. The plan was not to use conventional

building methods due to the tectonic location – Ica is situated in earthquake zone XI. A special earthquake test carried out at the Pontificia Universidad Católica del Perú PUCP on a prototype house from the plant confirmed earthquake safety up to level 9 on the Richter scale. Earthquake safety is

achieved by modular construction, a special reinforcement design and Llaxta's self-developed connector system.

The monolithic production method also saves on materials and is particularly cost-efficient along with other advantages:



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Fig. 15: Final assembly on site



Fig. 16: Show homes in "Las Piedras de Buena Vista"

- Fewer steel cores are necessary for reinforcement
- At the same time, greater stability of the overall system is achieved
- There is no need for expensive special components to join the various elements
- The expenditure for finishings, such as pipes or cable looms, is reduced. They are positioned directly during production, i.e. before the concrete is introduced into the mould. There is no need to connect them up later
- There are no joints and therefore no leaks between the individual walls or the walls and floor.

Upcrete modular housing functions as an integrated, closed system. All components have already been adapted to each other during the preceding development work.

This enables production even with unskilled workers who become specialised while using the system thanks to specific training in the machine technology and whose experience increases at the same time. All the essential and quality-critical aspects of the production processes are specified by

the technology which minimises human errors and ensures consistently high quality.

Upcrete technology is unrivalled

Where it was previously very time-consuming and complicated to produce room modules or to employ modular construction methods, the upcrete modular housing system offers a usable, cost-effective and so far unrivalled solution, particularly for affordable housing and low-cost housing projects. At a sale price of less than USD 25,000, a private home in Ica is very affordable by Peruvian standards.

Even for a project of this size and duration, it is possible with the modular housing system to reliably forecast material consumption, costs and profitability without the customer experiencing any surprises. It is essential that the demand for living space functions within the market as is the case in Peru. A modular housing solution with upcrete which optimises the investment volume and at the same time guarantees the project's profitability can also be prepared for projects with other key data with the right basic conditions.

Prospects

Production in Ica has been running since 2013. Other projects are already on the starting blocks. Gabriel Macedo, General Manager of Llaxta, sees large development potential: "We aim to position as a leading company in the industrialization of the housing and have a proven system at hand to build more efficiently, economically and fast, which is adaptable to other countries with similar problems in the housing sector, as we have them in Peru." Jörg Reymann, Managing Director of Ratec and Reymann Technik adds: "The challenge of creating reasonably priced, safe living space exists throughout the world. With the upcrete modular housing system we have a ready-to-use solution which is clearly superior to other methods of production under appropriate conditions. Modular housing with upcrete is earthquake-proof, environmentally friendly, material-efficient and economically viable. We will continue to develop our system to make it usable for other climatic conditions, more complex geometries and larger dimensions".



Fig. 17: Internal views of show homes



Fig. 18: The outdoor areas with sports and recreational facilities are created at the same time



Fig. 19: Example of conventional construction methods in Peru



Fig. 20: Building progress within a very short time

The name of the housing development in Ica – "Las Piedras de Buenavista" – means more or less "cliffs with a good view". He stands by his claim for the whole project and for the opportunities that prefabrication with upcrete offers. The Reymann Group thus provides previously undreamed-of possibilities and stimuli for those planning and designing the living space of the future.

About the Reymann Group

Reymann Technik is one of the oldest independent engineering firms for the development and implementation of leading edge precast concrete plants. Founder Wolfgang Reymann designed the world's first CAD/CAM-controlled pallet circulation system for the production of precast floor slabs in 1987. Now in the second generation, the company founder's sons, Mathias, Andreas and Jörg, continue to develop the expertise which has grown over more than 40 years. Sister company Ratec has been developing rational formwork solutions for more than

20 years and now delivers its products to customers in over 72 countries. From the switchable magnetic box to leading edge formwork systems for automated circulation plants and special formwork solutions, Ratec has decisively shaped and advanced the development of magnetic formwork technology.

With upcrete, the corporate group has developed an innovative process that sets new standards for the vertical production of everything from precast concrete elements to 3D room modules.

Llaxta is engaged in the development and industrialization of housing projects with the goal to provide high-quality living space, that is safe, affordable and rapidly available. Using industrial methods, Llaxta achieves standardization of construction processes by optimization of material consumption, cost reduction and specialization of labour. Llaxta was initially born by the idea to offer solutions for the growing demand in the housing market, resulting from economic growth and leading to a deficit in available living space. They now offer an alternative housing solution for large settlement projects. ■

FURTHER INFORMATION



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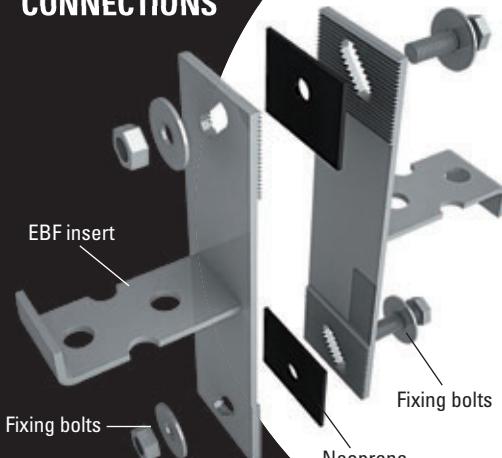
panel to panel connections

Edilmatic solutions for prefabricated elements

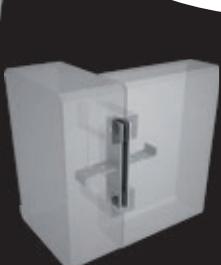


Configuration for "Adjoining" walls

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