Rural Appropriate Technology: Using Locally Available Wires for Pre-tensioning

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Abstract

The prices of the building materials are skyrocketing in these days in almost all developing countries, resulting in disturbing the picture of dream home from a mind of middle class rural citizens. This paper reports the results of an experimental study of the thin concrete slab panels with concrete beams pre-tensioned with locally available galvanized iron wires to prove a low cost and effective substitute for conventional pipe purlin supported GI sheet roofing system, using the concept of Rural Appropriate Technology (RAT). Wires used are up to 4mm diameter with recorded ultimate tensile stress is up to 700N/mm^2. Being located tropical region the temperature variation in central India ranges from 7^o to 45^0 which makes the conventional roofing system almost useless in summer. The proposed roofing system will help to solve this problem to a considerable extent as concrete bad conductor of heat. This system also helps in bringing down the cost of roofing, promoting the use of locally available labourer to slowdown the movement of rural people towards metros, and use local material to reduce overexploitation of natural resources.

Keywords: Low cost housing, Pre-tensioning, Concrete, Tensile stress, Rural appropriate technology

1. Introduction

With ever increasing cost of building materials the construction moderate size and medium quality dwelling is becoming very difficult in rural India. To empower the economically backward rural semi urban masses of the country people the Government of India has implemented the scheme "Indira Awaas Yojana" since 2002 which helps in construction of houses. The dwelling proposed by this scheme is having sloping Galvanized Iron sheets supported by pipe purlin. The head room on one side is 2.7m (9') and 2.4m (8') on other side which is major cause for raised temperature inside the house. In the tropical belt of India the highest temperature start to cross 35^0 C from mid March which continues up to June end. These elevated temperatures make the house almost useless for said period of the year. Both purlin and sheets are of steel proves the roofing a costly item. There is every possibility that the sheets and purlins get corroded.

Rural Appropriate Technology can be broadly defined as Technology relevant to real social needs that is accessible, affordable and empowering to the communities it serves and that use it. Rural Appropriate technology has Requirement as, only small amounts of capital, emphasizes the use of locally available materials, relatively less labour charges, and is affordable to individual families. Be understood, controlled and maintained without high levels of education and training, be able to be produced in small shops and villages, be adaptable and flexible, and include local communities in the innovation and implementation stages. Ultimately, RAT should not have any adverse environmental impact. The rationale of RAT resides in its empowerment of people

at the grass roots level. Engineer's awareness of cultural diversity issues, social and ethical concerns, and the practice of proactive environmental stewardship are all important components of utmost importance in RAT. Developmental professionals agree that local needs can be met more effectively with the community working to address their own needs. Tools that are developed should extend, not replace, human labour. RAT also emphasizes controllable scales of activity. The rationale is also grounded in the minimization of financial, transportation, education, advertising, management and energy services and costs with the goal of engendering self-sustaining and expanding reservoirs of skills within a community.

With a broad overview and an in-depth study of rural appropriate technology, grounding the study in an understanding of, and appreciation for, the ethics and philosophy of technology and its uses in rural, a cost effective, maintenance free and relatively eco-friendly substitute to the conventional roofing system is developed. The scope of the study covers national perspectives on housing for economically weaker sections of the society, defining the problems and efforts that should be made for solving the existing housing problem. The speed of construction can be geared up by using simple tools; using locally available material, training local labour and using simple techniques. The economy is growing at a slow pace, labour needs are changing, employment opportunities will always be slim for a certain portion of the population, and education levels will always make it such that not everyone is easily employable, or earns a high salary. This paper also deals with the experimentation of low cost housing for below poverty line and tsunami affected areas, and also the use of innovative materials such as crushed sand, ferrocrete, locally available wires and Panel housing.

The broad objective of the study is to present a global perspective on low cost housing technologies and present the state of the art of the latest innovative technologies for manufacturing precast building components and to promote and encourage the adoption of appropriate and affordable technologies on low-cost housing like pretentioned techniques.

2. Methodology

Prestressing is the application of a predetermined force or moment to a structural member in such a manner that the combined internal stresses in the member, resulting from this force or moment and from any anticipated condition of external loading, will be confined within specific limits. Prestressing, in its simplest form, can be illustrated by considering a simple, prismatic flexural member of rectangular in cross section stressed by a concentric or eccentric force. It is easily seen that if the flexural tensile stress in the bottom fiber, due to the live and dead loads, are eliminated by the compressive stress due to applied prestressing is equal in magnitude to the sum of this stress resulting in zero stress at working load. Pretensioning and post tensioning are the two types to achieve aforesaid effect. For the present study former type is adopted for pretension the slab panels in which time-dependent reduction of in the prestress, due to the elastic shortening, creep and shrinkage of the concrete and the relaxation of the prestressing steel. If no tensile stresses are to be permitted the concrete, it is necessary to provide an initial prestressing force that is larger than would be required to compensate for the flexural stresses resulting from the external loads alone. Generally result in a reduction of the initial prestressing force by 10 to 25 %. Therefore, if the stress distributions are desired after the loss of stress has taken place under the effects of the final prestressing force, the distribution of stresses under the initial increased prestressing force would have to be considered. Prestressing with the concentric force just illustrated has the disadvantage that the top fiber is required to withstand the compressive stress due to prestressing in addition to the compressive stresses resulting from the design loads.

It is evident that the average stress in the beam, prestressed with the eccentric force will be less than that required for the beam with concentric prestress. Therefore, the total prestressing force required to develop the desired prestressing of the second case will be less than that required in the concentric prestressing. The economy that results from applying the prestressing force eccentrically is obvious. Further economy can be achieved when small tensile stresses are permissible in the top fibers-these tensile stresses may be due to prestressing alone or to the combined effects of prestressing and any external loads that may be acting at the time of prestressing as shown in Figure 2.1. This is because the required bottom fiber prestress can be attained with a smaller prestressing force, which is applied at a greater eccentricity under such conditions. Lever arm technique for tensioning of wires can be adopted for case involving smaller magnitude of prestressing force, which can be induced with manual labour. A laborer with average physic can induce a force up to 7 kN.

For the present study slab panel was Pretensioned with concentric wires while the beam was with eccentric wires. These wires were tensioned with the simple screw jack and wire holding devices. The prestressing force required can be varied by adjusting the turns while tightening the screw jack.

3. Testing of materials and concrete mix design

3.1 Tension test of wires

This test was aimed to determine the tensile strength of given specimen of wire and to plot the stress strain curve to study the effect of tensile loading. To evaluate mechanical properties of material in a initial period, tensile test is most useful information about yield strength ultimate tensile strength for locally available wire. Stress-strain diagram shows the performance of tested material by graphically expressing the stress exerting in the specimen as a function of strain of pulling action of the Universal testing machine (UTM) from the start of pulling to the occurrence of failure.

Before the test gauge length (L_0) is marked on the specimen. After the specimen is tensioned by the matching deformation is measured with the help of extensometer. The extended length (L) at any point of loading is original length plus the elongation. The results of the test are presented in Table 3.1 and the stress strain curve is plotted as Figure3.1.

3.2 Concrete mix design

As the target is low cost housing the concrete mix used is M20, for which the mix is designed using IS method of concrete mix design. For this mix design all ingredients as cement, fine and coarse aggregate were tested as per standards. The proportions of ingredients and water cement ratio are as per Table 3.2 and the casted slab panel is as shown in Figure 3.2.

4. Design of members

4.1 Pretensioned Slab

Preliminary data:

Assumed live load = 1.5kN/ m^2

Thickness of slab = 0.025m

Self weight of slab = 0.025 x 25

= 0.625 kN/m

Total load on slab = 1.5+ 0.625

= 2.13 kN/m^2

Assuming 1m width of slab so 2.13kN/m^2 X 1.0 m

=2.13kN/m

From Figure 4.1

Bending Moment Calculation:

Assuming spacing of beam = 0.6m

B.M.max = 2.13 x 0.6^2/8

= 0.09kN-m

stress = M.y/ I

= (0.09X10^6 X 12.5) / (1000X 25.4^3/12)

=0.864N/ mm^2

Prestressing force calculation

P = 0.864 x25400

(C/S Area =25.4 x 1000)

= 21.94kN

Assuming prestressing loss of 20%

Loss ratio R_o= 0.80

Therefore P_o = 21.94/0.80

= 27.43 kN

Required area of Prestressing steel

A = 27430/ 0.8 x 716.19

(i.e., by 80% stressing)

(Where 716.19 N/mm^2 is yield stress obtained for 4mm diameter wires)

= 44.39 mm^2

Number of wires of 4mm diameter

= 44.39/ ((π/4) x 4^2)

= 5 number of wire at 250mm c/c

4.2 Design of Pretensioned Beam

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Preliminary data: Assume beam of 100 mm x 200 mm
Dead load = 0.1x 0.2 x 25
= 0.5kN/m
Load from panel = 2.125 x 0.6
= 1.28kN/m
Total load = 0.5 + 1.28
= 1.78 kN/m
Bending moment calculation
B.M.max = $wL^2/8$
= 1.78x3x3/8
= 2kN-m
Prestressing force calculation
$P=A [[(M \times y_b \times y_t)/(I \times D)]-F_{tw}]$
Where A=Cross Sectional area of Beam ,0.02 m^2
M=Total moment ,2x106 kN-m
= 29.97kN
Assuming prestressing loss of 20% R0= 0.80
Therefore P_o = 29.97/0.80
= 37.46kN
Area of Prestressing steel
= 37.46x1000/0.8x716.19
= 65.38mm^2
Number of wires of 4mm diameter
=65.38/π x 4
=6 nos. of wires
Eccentricity calculation
$e=1/p [M_d + (M_l x Y_b)/D]$
=43mm

5. Fabrication of moulds and tensioning device

Reusable mild steel mould was fabricated with ISMC 75 for the slab panel using bolts for molding and de-molding. The size of mold was decided so that a labourer with normal physic can lift and shift it. The thickness of concrete panel was anticipated as 25 mm so other dimensions were decided as 1050mm x 600mm. the expected weight of the panel was 35 kg. Holes at appropriate locations were drilled for introduction of Pretensioning and distribution wires. For beam the mold was fabricated with ISMC 75 and 6mm thick plates with holes using bolts for molding and de-molding. Waterproof plywood 9mm thickness was used for bottom and sides for a beam of size 100 x200 x3000 mm

A tensioning device is designed with 16mm diameter bolt with 2.3mm pitch and 10mm thick mild steel plates for frame, supports and guides. The wires were tensioned by turning the bolt for desired turn and held in position with help of anchorages borrowed from Dynamic Prestressing.

6. Testing of elements

Pretensioned slab panels and pretensioned beam were tested at the age of 28 days for flexure. An attachment was designed for universal Testing Machine to test the elements for two point load bending as shown in Figure 6.1.

7. Results and discussions

The Pretensioned slab panel was designed to carry accessible roof live load and self weight. The testing of this panel for two point load bending test shows that, the panel shows first crack on tension side at moment approximately 40% more than the anticipated at average deflection of 1.4 mm at midspan of simply supported panel of 600 mm span. There after the load carrying capacity increase with slower rate compared to that of the deflection and crack width. Most of the slab panels failed by crushing of concrete at midspan region on compression side. Few panels also failed due to crushing at supports. It was noted that, there was perfect bonding between concrete and the prestressing wires. Since the prestressing was concentric i.e. the wires were at mid depth of the section, fall at neutral axis due to bending and the force in the wires was less compared to their ultimate strength. None of the wirers found broken at the time of failure. The moment curvature relations are shown in Figure 7.1 Beam 3m long was prestressed with 6 wires of 4mm diameter at an eccentricity of 43mm below neutral axis in total depth of 200mm. During testing the behavior was as anticipated. The simply supported span for flexural test was adopted 2.84m. The cracks propagation started at 50% more moment than

anticipated design moment, exactly at midpan on tension side when the deflection was approx 5.5mm. More crack started developing in the vicinity of the first one with increase in the loading with rapid increase in deflection. The failure was due to yielding of steel on tension side. In one specimen the crushing of concrete at support was also noted, this may be due poor concrete at end portion of the beam and absence of stirrups. No failure due to breaking of pretensioining wires is recorded.The moment curvature relations are shown in Figure 7.2 .

8. Conclusions

1) The proposed pretensioned roofing system is structurally safe as the stress pattern is as anticipated in design of slab panel as well as beam.

2) Major drawbacks of raised temperature with GI sheet roof with pipe purlins is totally overcome

3) No question of rusting and safer than GI sheet roof in high velocity wind or cyclone prone coastal region

4) The technology of modern civil engineering i.e. prestressing can be used in rural areas for housing can be implemented with minimum cheap and simple instruments

5) The present roofing system will be more durable, serviceable and safe than GI sheet roof.

6) The proposed method can be easily adopted by the Government and Non Government Organizations for enhancing the life style of the downtrodden of the society

7) The locally available material and labour is utilized which helps in solving the evergreen problem of unemployment to certain extent.

8) The effectiveness of the proposed system can be further enhanced by making use of eco-friendly and recycled materials like fly-ash and crushed sand, with appropriate modifications in mix design.

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Table 3.1 Tension test data for wire

Description	Diameter	Length	C/S area	Max. load	Final length	Diameter at failure	%age elongation	Ultimate stress
Results	4	250	12.56	9700	330	1.5	32	772.29
Unit	mm	mm	mm^2	N	mm	mm	%	N/mm^2

Table 3.2 Mix design data

Basis	w/c	Cement	Fine aggregate	Course aggregate
Mass (kg)	0.50	400	669.81	1071.70
Ratio	0.50	1	1.67	2.67
Cement bag (per bag of 50kg)	27 lit	50	83.5	133.5

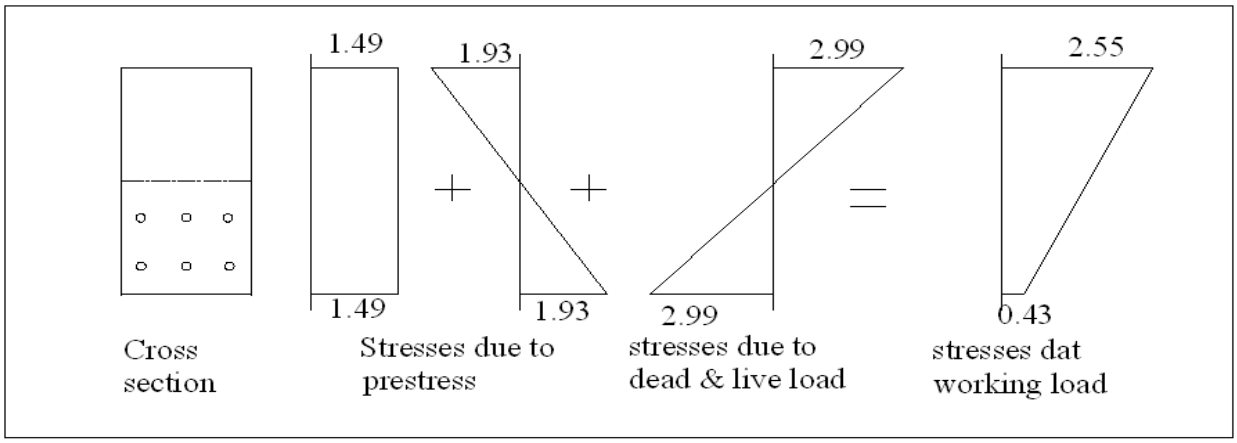

Figure 2.1 Stress Diagram at working load Condition

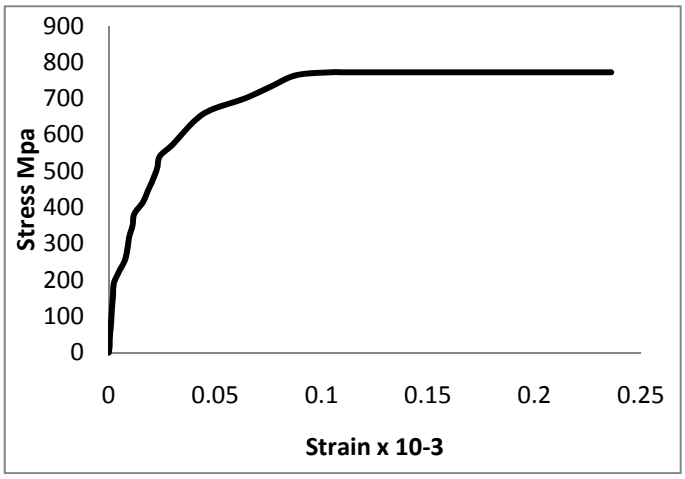

Figure 3.1 Stress Strain Curve for 4mm diameter wire

Figure 3.2 Pretensioned slab panel

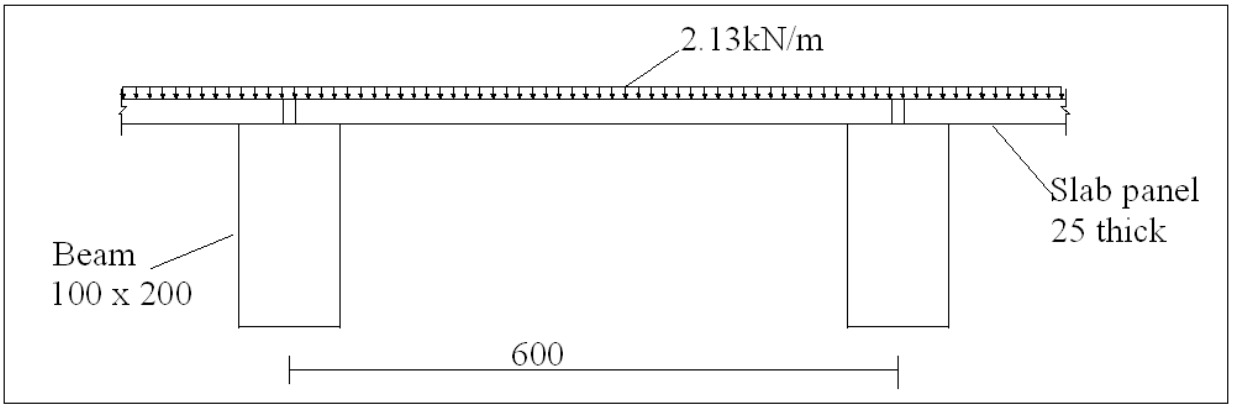

Figure 4.1 Cross section of proposed roof with loading

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Figure 6.1 Bending test on Pretensioned beam

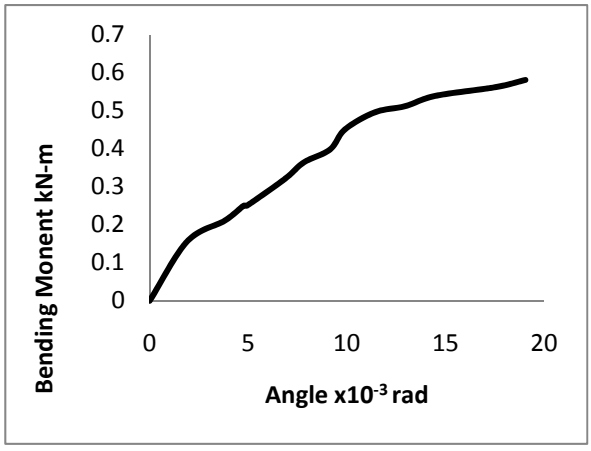

Figure 7.1 Bending test on pretensioned slab

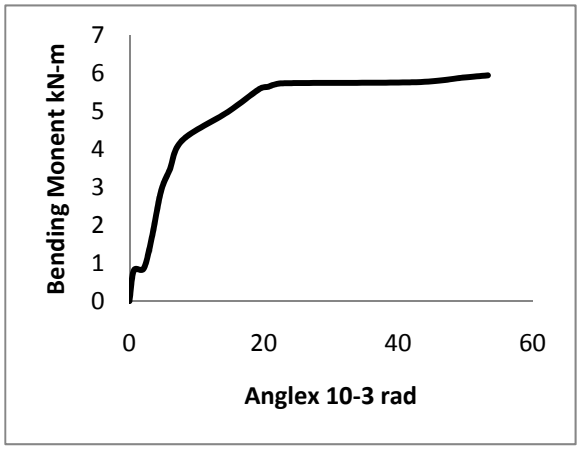

Figure 7.2 Bending test on pretensioned beam