An Experimental Analysis on Mechanical Properties And Engineering Properties of Modern Timber Under Tsunami Load

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Abstract- *This Paper is aimed to develop an analysis report of a modern timber bridge with tsunami forces. Modern timber structure holds many virtues in the fields of construction such as energy saving, green ,astheticsetc superior to concrete and steel bridge. Its mechanical properties of timber structure has attracted much attention than other structures. By previous studies states that the engineering application of modern timber CLT comprises an enormous potential as a prefabrication, joining techniques, building physics and building construction make it possible for timber engineering to achieve worldwide success. This thesis provides an overview of current production of material and characteristics of CLT. This paper represents the analysis of an tsunami loaded structure with modern timber to be used in construction.*

I. INTRODUCTION

Timber is considered as one of the most sustainable materials requires less energy than most material to process into finished products. Timber logging, manufacture, transport, and disposal of timber products have substantial environmental impacts.

Tsunami is the naturally occurring series of ocean waves resulting from rapid large scale disturbances in a body of water caused by the earthquakes, landslides and volcanic eruptions.

Here this paper investigates the mechanical properties and engineering application of modern timber for a bridge in china under tsunami loads

II. LITREATURE SURVEY ON TIMBER

RosemaryJ. Kennedy et. al (2005) described the use of timber in residential construction and developed the system for integrating timber products and aimed at a contemporary, environmentally sustainable housing approach for qualities of timber housing**.**

Ronald W. Anthony et. al (2005)analyzed that wood construction should have economic competitiveness and must provide reliable service in the existing building and prepared to know the next generation of engineers comfortable with wood construction.

Abimaje J. et .al (2014)assessed various building materials for its sustainability using data from various secondary sources. They established a new idea that a sustainable building material must be environmentally friendly, affordable, flexible in usage, and durable. They also discussed various problems associated with the usage of wood, such as attack by insects, fungi, fire, depletion of natural resources, etc. and preventive measures.

Jim Hart et. al (2020) studied that the built environment is one of the greatest contributors to carbon emissions, climate change, and unsustainable pressure on the natural environment and its ecosystems**.** which identifies a “substantial increase in the use of wood in the construction of buildings” as a top priority.

Dinwoodie J. M. Timber et. al (2020) analysed that Wood is a natural resource capable of being grown in most parts of the world. It is possible to grow an endless supply of timber. The environmental benefits of wood are immense. Trees absorb CO2 from the atmosphere, store the carbon and release O2 to the atmosphere, and so wood forms a carbon sink – which is unique for an engineering material. Timber harvested from trees and used in construction continues to store carbon. The carbon is only released back into the atmosphere when the wood decays or is burned.

A.H.L.Swaroop., et al. (2016) A review report suggest that tsunami loads exerted on structure can be obtained in terms of hydrodynamic, surge and impact forces for the given depth of inundation and the velocity of approaching tsunami. A building configuration can be so arranged that the tsunami waves pass through the opening at lower floor levels. The protection against tsunami can be achieved to the construction of sea walls, beach defenses and dense tree plantation along the coastal belts.

S.Selvamuthukumar ., et al (2014) A study conducted after the 2004 tsunami in 18 coastal hamlets along the south east coast of India reiterates the importance coastal **mangrove vegetations** and location characteristics of human inhabitations so to protect life and wealth from fury of tsunami Tsunami evacuation system incorporating several elements such as follows:

A complete protection by bio shield protection by mangroves and woodlands .

Proper land use planning (at least 1 km away from the coast).The evacuation building (EB) should be raised on columns to allow the sea water to pass beneath the structure and open in the other times to make activities. .

P.Kodanda Rama Rao .,et al. (2010) - This paper suggest that tsunami loads exerted on structure can be obtained in terms of hydrodynamic, surge and impact forces for the given depth of inundation and the velocity of approaching tsunami.A building configuration can be so arranged that the tsunami waves pass through the opening at lower floor levels.

III. TIMBER

Timber is considered as one of the most sustainable materials requires less energy than most material to process into finished products. Timber logging, manufacture, transport, and disposal of timber products have substantial environmental impacts. Sustainable timber refers to timber that has been harvested responsibly from well-managed forests that are continuously replenished, and ensure that there is no damage to the surrounding environment. Timber can be used for construction have good compressive strength, however, it is strongest in tension.

QUALITIES OF TIMBER

- Workability
- Physical and Aesthetics qualities
- Availability
- Environmental sustainability
- The flexibility of space arrangement
- Dry construction

APPLICATION OF TIMBER AS A SUSTAINABLE BUILDING MATERIAL

Sustainable building material is the one that does not have much negative impact on the environment. The use of sustainable materials for constructing buildings is not a new concept. The demand for environmentally friendly materials is rapidly increasing. People make us feel that wood is good for future generation and development. Wood grows from the earth is 100% renewable and extremely durable and equally strong.

CHALLENGES OF TIMBER AS A BUILDING MATERIAL

Fire - The greatest disadvantage of timber building is fire. When timber burns, it gets momentarily protected by its charring, which creates an insulating layer that reduces the speed of the spread of fire.

Weathering and decay - Timber decay arises from the fungal attack in combination with excessive moisture. The effect of weathering can be prevented through the coatings on the surface of the timber. If proper coatings should be done on the surface of the timber the timber should be safe on weathering agencies and decay.

Termite infestation- Termite control is of very high importance, however, the termite encroaching into a dwelling is not dependent upon the type of frame used in construction. Some of the processes involved in controlling termite infestation are suppression, site management, soil barriers, and choice of foundation

IV. TSUNAMI LOADING EFFECTS

According to camfield (1994) the following types of forces may result in tsunami run-up strikes the building with high velocities

1. Hydrostatic force
2. Hydrodynamic force
3. Buoyant force
4. Impact force
5. Surge force

In the analysis hydrodynamic and impact forces are predominant compared to other forces.

Hydrostatic forces Hydrostatic forces caused by partial or fully submergence of structures. The hydrostatic force per unit width is calculated using the equation

$$F_{hs}=\frac{1}{2}\rho g\left(h+\frac{u^2}{2g}\right)^2$$

Where ρ is the sea water density, g is the gravitational acceleration, h is the tsunami wave height and u is the normal component of tsunami wave flow velocity.

The equation is adopted by CCH (2000), hydrostatic force is usually important for long structures.

Buoyant force

When the full building is submerged by tsunami waves, it will be affected by the buoyant force, which is vertical force acting through the centre of mass of submerged body.

$$F_b = \rho g v$$

Where v is the volume of water submerged in building

Hydrodynamic force

It caused by high velocity of surging water.

$$F_d = \frac{1}{2}\rho c_d A u^2$$

Where c_d is the drag coefficient for the structural members.

Surge force

Surge force caused by leading edge of the surge impinging on a structure. Based on research conducted by Dames and Moore CCH (2000) proposes the following expression for the computation of surge force which is proportional to the square of the tsunami wave height. The surge force per unit width Fs is calculated by using equation

$$F_s = 4.5\,\rho g h^2$$

Where h is the tsunami wave height, assumed equal to the tsunami wave inundation depth.

Impact forces

It caused by driftwood, small boats, lumber, portions of houses and other debris material carried away by surge water.

CCH (2000) recommends the equation for estimation of debris impact force F_i

$$F_i = m\frac{u}{\Delta t}$$

Where m is the mass of the body impacting the structure assumed to 455 kg in CCH (2000) , u is the velocity of body assumed equal to the propagation velocity of a tsunami wave.

V. TSUNAMI RESISTING TECHNIQUES

To resist the loss of life by tsunami waves, the following techniques are implemented

By providing vertical evacuation
By planting vegetations
By providing sharp edged structure towards the tsunami wave
By providing hallow block wall as partition walls.

Vertical evacuation

A vertical evacuation refuge tsunami buildings (or) earthen mound that has sufficient height element evacuations above the level of tsunami inundation and is designed and constructed with the strength and resiliency needed to resist the effects of tsunami waves. Tsunami near sources generated approximate warning time is 30 minutes. (FEMA P-646 / APRIL 2012).

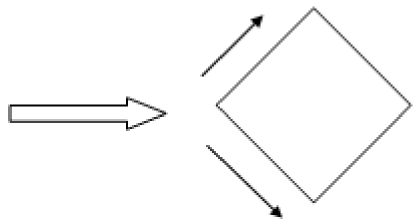
By (Tsunami Gupta / June 2005), the maximum run-up level (tsunami inundation wave level) in Nagapattinam (light house) is 3.9metre, the distance of seawater inundation in land is 750 meter.

Shape of structure

A structure is hydrodynamically shaped to offer protection from high waves.an example of such architecture is where a laminar flow around a building will protect the walls.

Laminar flow

A laminar flow occurs when a fluid flows in parallel layers, with no disruption between the layers. At low velocities the fluid tends to flow without lateral mixing and adjacent layers slide passes one another like playing cards. there are no cross currents perpendicular to the direction of flow. In laminar flow , the motion of the particles of the fluids is very orderly with particles close to the solid surface moving in straight line parallel to the surface.



Laminar flow is a flow regime characterized by high momentum diffusion and low momentum convection. When a fluid is flowing through a closed channel such as a pipe between two flat plates, either of two types of flow may occur depending on the velocity and viscosity of the fluid.

Planting vegetation

Some planting vegetation reduces the forces of tsunami waves like casurina and other bushes.

Analytical model shows that the 30 trees per 100 m^2 may reduce tsunami flow rates by as much as 90% (Tsunami proof design by Qin Rong).

Hollow blocks

Hollow block masonry can hold a body of water to sustain a family.

VI. MECHANICAL PROPERTY of TIMBER

PARALLEL TO GRAIN

- The parallel-to-grain direction is the strongest and stiffest from a structural perspective.
- The tensile strength of softwoods parallel to grain at 12% moisture content generally ranges between 70 to 140 MPa.
- The compression strength is lower and is usually in the range 30 to 60 MPa.
- For hardwoods, these values are generally higher.

PERPENDICULAR TO GRAIN

- Perpendicular-to-grain properties are significantly lower than the equivalent parallel to grain properties.
- The tensile strength in the radial and tangential directions can be as low as 5 to 8% and 3 to 5%, respectively, of the values in the grain direction.
- Compressive strengths perpendicular to grain are approximately 10 to 20% of the parallel to grain values.

FLEXURE AND SHEAR OF TIMBER

- The most commonly referenced strength property of wood is its modulus of rupture. This is defined as the bending stress in a flexural member at the failure load and is computed assuming an elastic stress distribution.
- Research has shown that size effects are important in flexural members as the larger the member the greater the probability of having a large defect which will reduce strength.
- In shear parallel to grain, the failure mode is quasi-brittle with shear strengths of about 5 to 12 MPa.

FACTORS THAT INFLUENCE MECHANICAL BEHAVIOUR STRENGTH REDUCING CHARACTERISTICS OR NATURALLY OCCURRING DEFECTS

- This timber is referred to as in-grade timber and it has inferior properties to clear wood due to the presence of strength-reducing characteristics or defects such as knots, slope of grain, gum veins, reaction wood, etc.
- Because of this, reliable mechanical properties of timber cannot be directly derived from the clear wood properties but must be determined by testing of in-grade specimens according to standardized procedures.
- In addition to a reduction in strength, the behaviour of structural timber is considerably more variable than clear wood as the pattern and frequency of defects varies from one piece to the next.
- Due to the random distribution of defects, the strength of a piece of timber depends on the size of the piece and the way in which it is loaded.
- Knots occur where branches joined the main stem of the tree and formed very efficient joints.
- They affect the strength due to the fact that the fibre orientations in the knot are generally perpendicular to the fibre direction of the member and the grain of the wood surrounding the knot is also severely distorted.
- The strength reducing effect depends both on the size of knot and its location.
- The larger the knot, the greater will be the grain deviation and resulting loss of strength.

MOISTURE

- The tensile strength is slightly reduced with increasing moisture content, with the higher grades most affected.

- The bending strength is also reduced with increasing moisture content and the failure mode in bending is moisture dependant.
- At low moisture contents, bending failures occur in the tensile zone, whereas at high moisture contents failures tend to occur in the compression zone.

DURATION OF LOAD

- The duration of load has a significant impact on both strength and stiffness.
- For a given magnitude of load, the strength of a timber member is reduced as the duration of the load increases.
- This loss of strength may be as high as 40%, which basically means the long-term strength for permanent loads such as self-weight or dead loads is only about 60% of that for the timber when it is first loaded in a structure.
- On the other hand, the duration of load effect on strength is less and the load carrying capacity is higher for members subjected to rapidly applied and very short term loading, such as peak wind events.

MEASUREMENT OF MECHANICAL PROPERTIES

- Standard test methods are available to determine the mechanical properties of timber. These tests are normally performed on timber that has been conditioned to about 12% moisture content.
- Tension and compression parallel to grain properties are found by applying an axial force to a test piece having a full-size cross-section and sufficiently long to provide a test length clear of the grips
- The modulus of elasticity is determined from the slope of the load-deformation curve. The tension or compression strength is found by dividing the failure load by the cross sectional area.

ENGINEERING APPLICATION OF CLT

- CROSS LAMINATED TIMBER can function a system-based approach for floors, walls, and roofs to form a high-performance, sustainable, and exquisite mass timber building of virtually any type
- A cross-section of a CLT element includes a minimum of three to five glued layers of boards placed in orthogonally direction to the neighboring layers.
- CLT products are fabricated with an odd number of layers; three to seven layers is common and even more
- Lumber within the outer layers of CLT panels used as walls are normally oriented up and down, parallel to gravity loads, to maximize the wall's vertical load capacity.

DESIGN OF STRUCTURAL ELEMENTS

Design of slab

The slab is designed for the load of 10 KN/m as one way slab
Check for moment

$Mu < Mu_{limit}$ section is under reinforced section
Check for shear
$\tau v > \tau c$
slab is safe against shear stress
Check for deflection
$(L/d)_{max} > (L/d)_{actual}$
Hence the slab is safety against continuous slab

Design of Beam

The beam is designed for the load of 12KN/m (including the self wt of slab)
Check for moment

$Mu < Mu_{limit}$ section is under reinforced section
Check for shear
$\tau v > \tau c$
beam is safe against shear stress
Check for deflection
$(L/d)_{max} > (L/d)_{actual}$
Hence the beam is safety against continuous beam.

Design of column

The column is designed for the ultimate load of 1500KN (including the loads of beam and slab)
Tsunami loads (by CCH 2000) Dames and Moore, tabulation

$F_T=F_b+F_d+F_i$ (For 4m height of tsunami inundation)
as 3027 KN.
Longitudinal reinforcement
0.98>0.8%
hence safe
lateral ties
1% >0.8%
Hence safe.
Column is designed for the diametre of 600mm.

Design of footing

Raft foundation is designed for this structure.

The footing is designed by including the column loads and tsunami loads.

Design of stair case

The doglegged staircase is designed for the structure

VII. CONCLUSION

In this research paper it is concluded that the following studies are done

1) The Mechanical properties of timber and the factors influence the mechanical properties of timber are studied
2) Tsunami loads caused by different water forces are studied
3) The engineering application of modern timber CLT comprises an enormous potential as a prefabrication, joining techniques, building physics and building construction make it possible for timber engineering to achieve worldwide success.

This thesis provides an overview of current production of material and characteristics of CLT

By using modern timber, a bridge in china was successfully constructed and it has remarkable significant.

The analysis report using STAAD PRO, Tsunami loads calculation for the structure and analysis of some selective parts of the Commercial building with tsunami loading and manual design calculation satisfying the necessary requirements as per indian standard codal specification have been presented above.The analysis report of the commercial building with deflection, stress , displacement and reaction also calculated for the tsunami loads.