DUCTILE OR NON-DUCTILE, THAT IS THE QUESTION.

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Introduction
New Zealand is currently grappling with the opportunities presented by a surge of interest in constructing medium rise commercial and apartment buildings in timber. NZ is earthquake- prone and for timber the anti seismic design demands do not readily combine with the other desirable requirements for acoustic isolation, vibration minimisation and fire control. This has meant that the majority of built projects have been designed in a manner to bypass the specific seismic design requirements of ductility.

A NZ- specific multi rise timber design manual has been under preparation for several years, with the purpose of bringing together all the research efforts and results relevant to timber construction for up to 6 storeys. This effort has identified several areas where further work is desirable but contentious points in design, in particular have meant this document is still not published.
An area of confusion is over the need, or otherwise, for designing to ensure a ductile failure mode for the primary structure.

Much of the present timber construction is concentrated in the north island (especially Auckland and its environs) where EQ risk levels are low, wind loads are often more critical allowing the design and construction to follow 'elastic' design methods. This method does not demand a ductile approach and the methodology can be similar to other non- EQ prone environments like Australia or UK. Most of the current buildings being constructed are non- ductile and are designed following elastic methods.

Design Methods
Elastic design methods make no demands for ductility of chosen elements and timber designs using this method, especially in the Auckland area, can be competitive with steel and concrete equivalents. This primarily due to the inherent low mass of the timber fabric generating reduced demands for lateral loads and reduced concrete volumes in the footings.

The NZ loadings code (NZS4203) is difficult to interpret on its demands for designing a timber structure in the local earthquake environment but where in many situations the wind force could be the dominant load.
Clause 1.1.3 of NZS 4203 (Scope)*, states The seismic provisions of part 4 of this standard apply only to structures (or elements) which exhibit non-brittle behaviour.* Since much timber design (especially glulam) is considered brittle this suggests NZS 4203 as written does not apply and any design would need to be the subject of a special study. However the cl 1.1.3 'commentary' declares that most timber framed buildings do show some ductility therefore NZS 4203 is an appropriate code to follow for that style of construction. A timber framed building using a moment-resisting frame (MRF) is within the code only when joints are ductile but this is not how it is used in practice, since buildings designed elastically include both MRF frame and wall frames.
The sense of this clause would appear that when seismic loads are the ruling load ductility is a must even if using elastic methods, whereas if wind is the predominant loading no ductility is required.

Clause 2.5.3 (Analysis and Design) has notes referring to the ultimate limit state and quotes the code as satisfied *'Where the analysis is based on the elastic method'*
Further under 2.5.3.4 *For combinations of factored loads not involving EQ's the structure and its parts shall be designed to prevent instability due to overturning sliding or uplift.* There is no mention here of identifying a particular mode of failure or the requiring of ductility when using this elastic design approach.
The code is ambiguous over a situation when wind is dominant but EQ is almost as large.
A general attitude among NZ designers is that any building in NZ could be subject to an EQ load and hence a mode of failure should be identifiable and natural ductilities should be detailed, or enhanced, wherever feasible.
It has been this attitude that has seen timber medium rise construction slow to develop as designers were not confident on how to satisfy the above requirements. NZS 3603 refers to *Earthquake effects* (2.12.4.) *'that a potentially brittle structure shall have design forces assessed using a ductility factor of 1.25'* however we suggest this is not saying the structure has ductility. Actual ductility to match a ductility factor of 1.25 is only achieved if the structure under test can survive 4 complete displacement cycles. (Appendix C4A, NZS 4203) The ability to physically test every design is hardly practical but the alternative of applying capacity design to strengthen the non ductile fabric does not take the designer into an area where the range of available research will readily prove his theoretical assumptions are correct. Despite the terminology, a ductility of 1 is interpreted as Elastic Design. Further, NZS 4203 clause 2.5.4.6 says that

capacity design only has to be used when a ductility factor greater than 3.0 has been chosen. For timber this means for any limited ductile structure the carrying out of capacity design can be bypassed. There is nothing in the material standard to support this approach.

Research information on expected ductilities of timber assemblages or frame joints has been slow to appear and suggested methods to divide up a timber structure so a definite mode of element failure could be identified has not been started.

We suggest that designing with timber wall framing to clearly identify a mode of failure and then ensuring those critical elements show the 'design assumed ductility 'would require major changes in NZ design and construction attitudes.

Elastic design (an acceptable design method under the code) makes no demands to identify a mode of failure but merely shows there is sufficient strength (and stiffness) available to resist the applied external load. If ductility is always desirable the Code should discourage the use of elastic design and clearly identify how different ductilities can be achieved with timber structural elements.

A reading of the present code indicates the NZ designer's attitude is over zealous and he/she is not formally demanded by the code to provide ductility etc for all projects.
This is supported by the current acceptance of design/ construction methods used in ordinary house construction (up to 2.5 stories), vertical load paths can be non aligned and walls (internal and external) with only minor special detailing can be mobilised for developing the design lateral strength. Results of recent seismic events such as Edgecumbe were evidence that these construction methods were generally sufficient. Few houses collapsed and a predominant (and repairable) mode of failure was where the timber homes merely dislodged off their foundations.

If this attitude continues to be acceptable (for structural wall dominated and moment resistant framing) timber, medium rise, buildings in much of NZ can be designed using elastic design methodology for wind or earthquake loads.
Ductile detailing and capacity design concepts are merely an option that can be explored and utilised if desired.

Conclusions
There has been, over the years since the mid 80's, an erosion of areas where in New Zealand timber buildings could traditionally compete with steel. Ongoing research by the steel industry (HERA and Steltech) has meant that purpose made steel members can be provided economically for commercial and especially industrial buildings. All connections have been clarified and ductility's demonstrated. In competition with this the timber option nowadays is often not the most economic. Many NZ design engineers will wish to achieve ductility in any structure, no matter what the design approach and this attitude should be encouraged. Clarification of demands in the Loadings Code is needed and the material standard extended to clarify 'capacity design' factors and procedures for a wider range of structural elements.

Growth in timber usage in the NZ building industry can only come from:
* Architects ----creating a deliberate design in timber where other material alternatives are not an issue
* Client /developers---considering alternative schemes using timber with proven well documented cost advantages. Currently this is only occurring in apartment buildings.
* Possible new areas --- such as medium rise commercial, suburban or fringe CBD.
This growth will not eventuate unless designers have a clear direction from Codes of Practice and are also confident that theoretical approaches match the practical realisation.

There is a demonstrable need for ongoing timber industry research to clarify expected ductilities of various timber assemblages especially newer EWP forms (eg Triboard). Results from this research would clarify aspects of the NZ loadings and material code that currently cover timber usage.

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