DESIGN AND PRACTICAL LIMITATIONS IN EARTHQUAKE RESISTANT STRUCTURES AND FEEDBACK

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ABSTRACT

The paper presents the various limitations in design and construction practices along with the feedback to overcome the limitations and make the structures safer to take the earthquake forces. The paper focuses on software used in the civil engineering for analysis and design, construction methods/practices, use of materials, types of structures, experiments for earthquake studies, quality control parameters etc.

Key words: Staad – Pro, Concrete, Grade of Steel, Welding, Binding Wires, Ferrocement, Slabs, Depth of Foundation, Soil- Structure Interaction, Shake Table, Etc.

INTRODUCTION

A) Design software

In civil engineering to analyze and design any structure there are various well known software like STAAD PRO etc. which are in use all over the world. Even though for end users there are limitations to use these software’s for correct/critical analysis. Now a day all over the world to analyze and design any civil engineering structures, structural engineers are using various well known software like STAAD PRO, SAP etc. In STAAD PRO the end users (civil – structural engineers) are assigning the live loads on all slabs/floors or separately on beams. Almost all structural engineers are assigning the live loads on all the floors /slabs/beams and analyzing the framed structures. But assigning the live loads on all the floors/beams is not being the critical case.
The critical case may be studied by substitute frame method for vertical loads, and for lateral or horizontal wind/seismic loads which can be analyzed by approximate method such as portal method, cantilever method, factor method etc. and critical case may be studied.

As in STAAD PRO the structures are analyzed by combinations of vertical and horizontal loads on the frames at a time by considering the live load on all the floors. But it is not a critical case because the live loads are assigned on all the floors.

If we take one example of multistory building having n number of bays and m number of storey. Then the analysis made by all most all structural engineers is not critical. e.g. in the design of slabs and beams the structural engineers are considering live loads on all the floors/beams and by using software they are analyzing and designing the structures.

If simply we consider one continuous slab or beam having spans more than three, it requires the various positions of live loads for critical case and which is not considered in the existing software. If the live load is considered on all the floors or beams it cannot give the critical case. If continuous slab or beam say having three or more spans requires various positions of live loads to get the maximum positive and negative bending moments in the span and maximum negative bending moments at supports. Also the nature of bending moment is also different for critical analysis which is not at all considered in the analysis and design by using any existing software.

If the continuous slab or beam ABCDEF having span equal or unequal lengths L is to be analyzed and design. Then if we are considering live loads on all the spans ( live loads considered on all the spans ABCDEF) then we will not get the critical case for maximum positive and negative bending moments in the span and maximum positive &negative bending moment at supports. The nature and magnitude of bending moments are also different for critical case which can be analyzed by considering various positions of live loads, suppose we want the critical bending moment in the span CD, then we have to load the spans in two different ways to get maximum positive bending moment and maximum negative banding moment in the span. To get maximum positive and maximum negative bending moment in span CD, the alternate spans should be loaded including span CD and alternate span should be loaded excluding span CD respectively.

So it requires studying the various positions of live loads and critical bending moments at various critical sections. Because critical case depends upon the various position of live load. 2 (ref. substitute frame method). So it is not possible or very difficult and laborious to consider all positions and number of trials of live loads even by using existing software to get the critical analysis. Critical analysis is highly impossible by using existing software, because it contains number of trials.

The critical analysis is requiring the maximum magnitude of bending moments and its nature which are different at various positions. If critical analysis is not done then the structures will not be more safe and durable. As in case span CD there it exists maximum positive and negative bending moment. And if we analyze by using the software, by analyzing loads on all the spans we are getting only positive bending moment in span CD and that is to be less than the critical case. And software cannot take in to consideration of negative bending moments in span CD. And because of that, structure is no longer safe for critical loading and though the load is not critical, also small hair cracks develop at the top of mid span of span CD as the negative banding moment in span CD is not considered in the existing software which leads to percolation of water and thereby corrosion of reinforcement also takes place, ultimately it reduces the life of the structure.

Feedback

Critical analysis is required for safe design. And to get the critical section it is necessary to improve the software which takes into account the number of trials i.e. various positions of live loads. The software should be improved in such a way that it should take automatically all positions of live load on floors/beams for critical analysis.
B) Role of mild Steel

The mild steel is more ductile which gives better performance in earthquakes and even its production cost is less. So use of mild steel in country up to its maximum extent can save life of people and improves the national economy up to great extent. The various grades of steels are recommended by Indian standard for civil engineering constructions. In India the use of tor steel (Fe415 and Fe500) is more than the use of mild steel (Fe250), almost use of mild steel is stopped. Now there is a big question that why the use of mild steel is becoming less and less, which is almost stopped? Is it because of its less characteristic strength? The answer is no. Then is it uneconomical? Again the answer is no because its production cost is also less. The mild steel is more ductile than the tor steel (Fe415 and Fe500) and gives better performance in earthquakes also and which is accepted by whole world.

Cost economics

If we design any civil engineering structure by tor steel and mild steel, definitely because of less strength of mild steel total area or weight of steel is more than the tor steel. But the overall production cost (not the current market cost) required for that particular area or weight of mild steel and tor steel are compared, then definitely it will prove that economy in the structure which is designed by mild steel. Not only economy, but mild steel also gives better performance even in earthquakes.

Feedback

Use of mild steel saves life of the peoples and improves the national economy up to a great extent.

C) Role of welding in earthquake resistant structure

In almost all countries the mild steel binding wires are in use to connect the two overlapped bars in reinforced cement concrete. If this use of mild steel bars is replaced by welding, we can increase strength and the life reinforced cement concrete structures. It is proved and accepted by whole world that in case of ferrocement structures, the structure in which welded mesh is used gives more strength and durability as compared to woven mesh for same area of steel. This theory is also applicable to RCC structures. As in case of bars connected by binding wires cannot transfer stress more effective as in case of bars connected by welding. Also we can save life of people especially in earthquakes. This small change will improve the national economy.

In reinforced cement concrete still date mild steel binding wires are in use to connect two overlapped steel bars. Even in developed and developing countries this practice of using mild steel wires are still in use. In case of ferrocement structures, the structure in which welded mesh is used gives more strength and durability as compared to woven mesh for same area of steel. This theory is also applicable to RCC structures.

Now days the structures are analyzed and designed by various methods. Lot of research work is going on, on analysis and design of reinforced cement concrete structures including seismic analysis. But still date focus on use of mild steel binding wire and weld is very limited. There is lot of study on corrosion in reinforcing bars, dynamic analysis and design of structures. But the focus on binding wire and weld is very limited, even in various national and international codes.

The durability of old structures definitely depends on whether the reinforcing bars are welded or connected by using binding wires. So if this use of binding wire is completely replaced by welding, leads to increase in life of RCC especially in heavy, marine structures, structures in earthquake zones etc.

Because of corrosion and use of insufficient binding wire to connect the reinforcing bars leads to failure of the structures before time, though the analysis and design is 100% correct. As in
case of bars connected by binding wires cannot transfer stress more effective as in case of bars connected by welding. The increase in strength will be 15 to 20% and life of structure will increase by 10 to 15 years.

Also beam column joints remains rigid which is considered in the analysis and design of the structures.

Feedback
This small change of replacing binding wires by welding leads to increase strength and the life of RCC structures, save life of people especially in earthquakes and improves the national economy.

D) Role of square and rectangular bars
In almost all countries the circular shaped bars are in use as reinforcement in RCC work. If these circular bars are replaced by square or rectangular bars the strength of RCC structures will increase. The mild steel is more ductile as compared to tor steel (Fe415 and Fe500), hence the earthquake performance of mild steel is better than the tor steel, and which is accepted by whole world. So use of square and rectangular mild steel bars gives more strength and better earthquake performance as compared to mild steel circular bars or tor steel circular bars. In almost all countries the use of circular bars as reinforcement in concrete is still in use. The mild steel is more ductile and its earthquake performance is better than the tor steel, and which is accepted by whole world. The use of rectangular or square mild steel bars in RCC will give the more strength and better earthquake performance than circular bars. For same area of steel, the specific surface area for square and rectangular bars are more as compared to circular bars, hence the bond strength is more in case of rectangular and square bars. Further the bond strength of rectangular and square bars can be increased simply by winding the mild steel binding wire in spiral form. Also the moments of inertia of square and rectangular bars are more as compared to the circular bars for same area of steel. Hence the strength of columns having square and rectangular bars is more than the strength of column having circular bars. Even from strength and earthquake performance point of view, the use of mild steel square and rectangular bars in other structural elements is better than the circular bars.

Also, it is reported in the study of ferrocement that welded meshes give more strength as compared to woven mesh for same % of steel. At present in all countries mild steel binding wires are in use to connect the two overlapped reinforcing bars. But if we replace the binding wires by welding then definitely we will get more strength and more life of RCC structures. Also in case of rectangular and square bars the available length for weld is more than the circular bars. so the development length required for square and rectangular bars is less as compared to circular bars.

Hence the use of mild steel rectangular and steel bars lead more strength and better earthquake performance, which leads the national economy.

E) Role of ferrocement grid slab and ferrocement jacketing for columns
The effective use of ferrocement grid slab reduces the dead load as well as it gives better earthquake performance as compared to conventional reinforce cement concrete slabs. Also the ferrocement jacketing in columns plays very important role to maintain the beam column joint more rigid so that it improves the better earthquake performance.

F) Some other important tips for earthquake resistant structure
1. Safe bearing capacity of soil, depth of foundation, soil structure interaction study should be very carefully studied before designing the structures.
2. Due care should be taken during design and construction to maintain the quality of work. e.g. the characteristic strength of the concrete should be taken account for design and maintaining the quality of concrete.

3. The construction of frames and walls should be done simultaneously so that walls can also share some load and there will not be any kind of failure of walls during the earthquakes, which may takes place in case of first constructed frame and there after brick walls as a partition wall.

4. As far as possible the center of gravity of the whole structure should be maintained at lower level.

5. Cantilever portions should be avoided.

6. Beam column joint should be made more rigid.

7. Sufficient correction factor should be applied to study the actual earthquake effect and the effect of earthquake studied by using shake tables.

8. Use of mild steel, welding provides the better ductile behavior and better earthquake performance along with achieving the overall economy.

9. Careful earthquake designs should be done before construction which takes in to account of various positions of live loads along with earthquake forces.

CONCLUSIONS

1. The multistory structures analyzed by improved software will be safer as compared to existing software.

2. Mild steel save life of the people and improves the national economy up to a great extent.

3. The stress or strain transformation is more effective in case of welding the two overlapped bars than the binding wires. It can be proved by performing small experiment by using strain gauges or sensors which we are using in health monitoring. This small change of replacing binding wires by welding leads to increase in strength and the life of RCC structures, save life of people especially in earthquakes and improves the national economy.

4. The use of square and rectangular mild bars in column and other structural elements give more strength, economy and better earthquake performance. So all civil engineers and govt. are requested to look in this matter. As it really save the life of people and improves the overall economy.

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