香港
鋼結構學會
Hong Kong Institute of Steel Construction

Bulletin

No.1 July 2001
http://www.geocities.com/hongkongsteel/
Issue Editor : Professor S. L. Chan
Ph.D., MIStructE, FHKIE FHKISC, CEng, RPE

We are very pleased to announce the establishment of the Hong Kong Institute of Steel Construction (HKISC) in November 2000. HKISC has been registered as a non-profit making organization with its board members representing universities, consultants, developers, contractors and laboratories in Hong Kong. HKISC serves the steel construction industry in Hong Kong and the neighbouring region and carries the following specific objectives.

Objectives

- Channeling of technology transfer between academics and industry for improved quality in design, analysis and construction;
- Making university research more practical and useful for practitioners;
- Informing and sharing of new technology worldwide among members ;
- Organizing seminars for local and overseas experts for dissemination of their technological know-how ;
- Developing and fostering friendship among members for exchange of opinions on complex problems ;
- Sponsoring international conferences on steel structures in order to allow sharing of expertise between local and overseas researchers and engineers and
- Publication of quarterly bulletin for news and new technology developed by local or overseas universities

We are very pleased to receive an inaugural message from Professor D.A. Nethercot of Imperial College, U.K. as follows.

"I am delighted to have this opportunity of applauding the insight and vision that has led to the creation of an Institute of Steel Construction in Hong Kong. The provision of an identified focal point for all those with an interest in and an ability to contribute to the development of steel construction in the region and in the neighboring area should bring about a strengthening of local capability and a better appreciation of the merits of steel as an essential
component in the provision of appropriate solutions to the construction challenges of the future. Not only has Hong Kong witnessed the appearance of several high profile, extremely successful and internationally well regarded steel structures such as the roof of the new airport, the Convention Center and the Tsing Ma Bridge, it also has a history of well known tall steel buildings such as the headquarters of both the Bank of China and the Hong Kong and Shanghai Banking Corporation. Structural steel also plays a vital role in less glamorous but equally valuable infrastructure projects such as the cross-harbor tunnels, cargo handling facilities and rail developments. Linked to this is the research and technical ability in Hong Kong's universities as well as experience in regulatory matters within Government departments and, of course, very substantial design ability within its consulting community.

Looking back to the formation of the Steel Constructional Institute (SCI) in the UK over a decade ago, it is now hard to imagine how the structural steelwork community functioned without its support. As a Vice Chairman of the Council of that organisation I wish the newly launched Hong Kong Institute of Steel Construction every success and trust that 10 years from now I will be able to reflect on an initiative that has produced a similarly beneficial effect for steel construction in the Asean region".

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Research and Technology Forum

Opinions expressed in this column do not represent that of the HKISC nor the affiliated organization(s) of the author(s). Further details can be sought directly from the author(s)

Viscous-Damping Walls against unwanted dynamic effects

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In the 21st century, in order to counter the dangers of earthquakes and wind-induced vibrations, we will likely see more and more buildings incorporating damping devices. As reported in Civil Engineering, "This upstart technology, once ignored, has now become more prevalent, with energy-dissipating devices employed for new buildings and retrofits alike."

Reliance on damping has always been an integral part of the design strategy for vibration control and energy dissipation in other engineering disciplines, for example, in the mechanical, automotive and aeronautical industries. Structural engineers are now beginning to think the same way. The natural damping present in building structures is very small and it was long thought that adding supplementary damping devices would be uneconomical. However, this is changing because prices of damping devices are dropping and their capacities are rising. One such device is the viscous-damping wall.

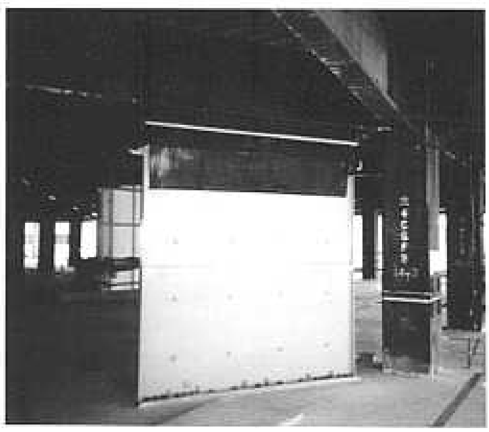
In the 1980's a Japanese engineer, Mitsuo Miyazaki, President of Dynamic Design Inc., was the first to propose the concept of injecting a high-viscosity fluid into the wall panels of buildings. As shown in Figure 1, his invention is a very practical and simple one -- consisting of high-viscosity fluid sandwiched by three wall plates. The inner steel plate is attached to the upper floor of a story; the two outer steel plates are mounted on the lower floor of the same story. A small gap separates the inner and outer plates where the viscous fluid (polybutane) is injected. When a building is subjected to dynamic forces induced by wind or earthquake, inter-story drift causes the inner plate to move relative to the outer plates. This action, due to the presence of the viscous fluid between the plates, generates restoring forces that reduce the dynamic response of the building. In comparison with other types of passive control devices viscous-damping walls have very high capacities for energy-dissipation because there is a large area available for the high-viscosity fluid to act on.

Viscous-damping walls were first successfully applied to a number of retrofit projects in Japan. The first new building construction incorporating viscous-damping walls was the SUT Building in Shizuoka City, Japan, completed in 1995. Measurements taken at the SUT Building have shown that the added viscous-damping walls increase the damping value of the building approximately ten times, to over 20 percent. In the SUT Building eight viscous-damping walls units (four in each direction) were installed in every story.

The first wind tunnel studies of viscous-damping walls were carried out at the University of Hong Kong and this research is reported in the Journal of Wind Engineering and Industrial Aerodynamics [Yeung and Pan, Vol. 77&78, 1998]. Response of the aeroelastic Zbuilding model before and after viscous-damping device installed is compared. Deflections were reduced by about 50%. Currently, testing is being conducted to investigate how the three-dimensional movements of a building (out-of-plane, rotational, and torsional) affect the reliability and efficiency of viscous-damping walls (research supported by the Hong Kong Research Grants Council).

Even though viscous-damping walls impose additional costs, the overall cost of the building is competitive. Since the risks associated with earthquakes and wind-induced vibrations are now countered by the viscous-damping devices, the building will require less strength, stiffness and ductility, reducing the cost of the structural framing system. Savings will also be achieved in the building's life cycle cost from lower repair costs after earthquakes.

Devices such as viscous-damping walls allow engineers greater flexibility to think about design strategy not only in terms of strength and stiffness, but also damping. Conventional structural design has long held fast to the idea that more strength and stiffness added to buildings would make them better. However, especially after the 1994 Northridge Earthquake, engineers have now come to recognize there are flaws in this kind of thinking. Sometimes designing a building for higher forces makes the building worse because it attracts more earthquake energy and the building must dissipate that energy through additional damage. During Northridge more than 100 steel moment frame buildings in the Los Angeles area were damaged more than was first thought, mostly due to premature fracture of welds. Many building owners and insurance companies are saying the likely level of damage with conventional seismic design is just too much.



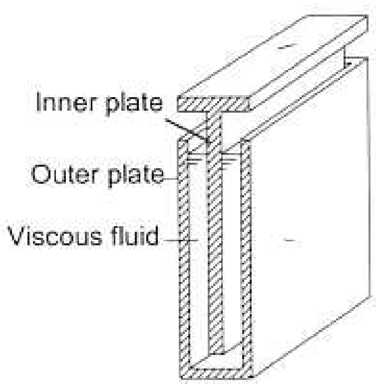


Figure 1. Viscous-damping wall
(photo courtesy of Dynamic Design Inc.)

Behaviour-based design of steel structures for economical, safe and efficient practical design

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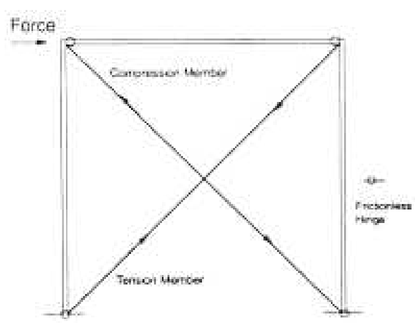
In pace with the advance in computer technology, modern design philosophy emerges. Prior to the mid twentieth century, engineers designed structures by limiting their maximum stress. This is the so-called allowable stress design method. Unfortunately, the capacity of metal and steel structures is affected not only by yield stress, but also by Young's modulus of elasticity and therefore the stress control may not be appropriate. Buckling strength is always a controlling factor in structures with members under compression. In the 1970's, the limit state design concept was developed and adopted in a number of national design codes. The limiting response of a structure was used as a yardstick for checking safety and the factored design load is applied to judge whether or not a structure exceeds its limits at ultimate and serviceability states. Recently, the performance-based design concept has been proposed to check the fitness of a structure against a series of performance criteria. In seismic and fire engineering, a structure is checked against these criteria under dynamic loads and elevated temperature and this approach has been replacing the prescriptive design rules in many countries.



Can your computer program tell you if force in tension brace is higher than in compression brace ?

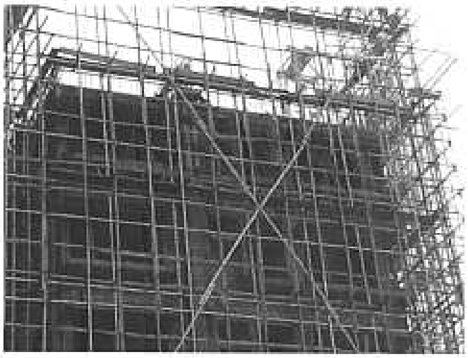
An even more rational and advanced design technology and concept has been formulated at the HKPolyU. To illustrate this, a simple portal with cross-bracing is considered below.

As the lateral load is increased gradually until failure of the system, the compression and the tension members share the load in accordance with their stiffness which, before material yields, becomes smaller under compression and larger under tension. When the compression member is about to buckle, its stiffness is small and does not allow it to take further load so all load is taken by the tension member. This means that the compression member will not buckle before failure of the tension member which cannot be illustrated in conventional design methods. Obviously, common structural analysis software based on this linear assumption cannot indicate this phenomenon and they show that both the compression and tension members take equal load. It should be noted that once the tension member fails, the system is considered to have reached its design capacity. This is because the design practice is based on the first plastic hinge approach limiting the design load level below the failure of any single member in a system.

The allowable stress, the limit state and the performance-based design methods cannot give a satisfactory answer on the load capacity of the structure. Even using limit state or the performance-based design concept, we cannot design the structure efficiently and safely because we do not know its behaviour and the performance criteria become impossible to specify. Experienced engineers assume the absence of the compression member and that only the tension member takes load. This is in line with our proposed behaviour-based design method which models the response of a structure in the analysis and the following design becomes natural and trivial. We can simply check the safety of the system under a simulated loading environment and the true structural behaviour. Using the computer program, NIDA (Nonlinear Integrated Design and Analysis, a software developed by the author at PolyU) we can see failure occurs in the tension member first since it takes a much larger load. A physical inspection shows that the tension member prevents excessive deflection at the top and thus assists the compression member against buckling. This involves relatively large lateral drift for member shortening.

The new behaviour-based design concept and associated software not only works in a simple environment, but also extends beyond it. When the compression member is not too slender, it helps in taking a measurable portion of load[1] before reaching its elasto-plastic buckling load. The conventional method of ignoring its contribution in taking load is too conservative and uneconomical. Furthermore, many practical members are of moderate slenderness so that only the behaviour-based design method is a reliable means for safe and economical design. Over-design of some members and under-design of others by the conventional method can be avoided. In addition, the manual inspection of a large structure is more time-consuming, tedious, unreliable and prone to human error.

Design of some structural forms are out of reach of our conventional method. For example, the design of a bamboo-steel scaffolding system involves complex buckling checks. The system intelligently uses stronger steel members as main members and bamboo members as secondary members which leads to a lighter and more economical scaffolding. However, the buckling strength of bamboo members cannot be determined by the conventional method, because there are no existing design codes for structural bamboo. However, using the behaviour-based design concept, the mixed scaffolding system is simulated with the use of statistically based test results of yield stress and Young's modulus of elasticity, with adequate allowance for large variation in bamboo properties. With these basic material properties, we can then determine the load capacity of a structure of an arbitrary form.



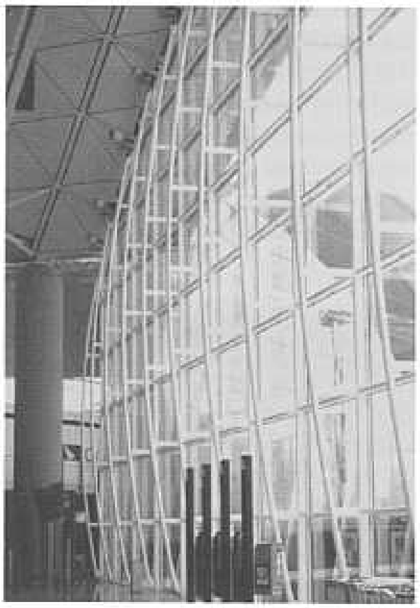
Mixed Bamboo-Steel Scaffolding System

A material failure stress of 40 N/mm2 and Young's modulus of elasticity of 10-12 kN/cm2 are used for the design of structures utilising species Phyllostachys pubescens and Bambusa pervariabilis which are the types commonly used in bamboo scaffolding in Hong Kong.

In the second example below, the effective length of the back chord in the direction perpendicular to

[1] buckling accompanied by material yield

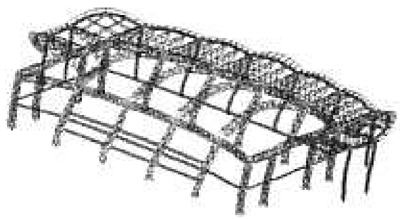
the plane of the truss in a bow truss system below is also uncertain by use of the conventional method. Again, using the behaviour-based approach of increasing the load until elasto-plastic buckling, we can determine the factored design load capacity of the system easily and reliably.



How to assess the effective length of the back chord of the truss in out-of-plane direction for safe and economical design ?

The design of a moderate sized structure like the Macau Return Memorial Hall can also be conducted by the behaviour-based concept used in association with NIDA by which we need not check the capacity of the members individually and their capacity levels are indicated by colour graphically. Note that design is completed simultaneously with analysis and that assignment of guessed (with uncertainty) effective length is not needed. This leads to improvements in design efficiency and is economical in overall structural weight. Other projects designed by this concept include steel-concrete composite high-rise buildings.

The computer model shows the deflected hall designed by the method under a 50-year return period wind speed with failed / buckled members in red (Deflection magnified). Design is completed simultaneously with analysis &, in the whole design process, no assumption of effective length is made & the results are more economical and safer than linear analysis which over-designs some members but under-designs others.



Industrial Forum

Cost Effective Steel Construction in Hong Kong

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I. Introduction

Under a steelwork contract with the building contractor, a company undertaking the structural steelwork construction work normally has the responsibilities to (1) prepare shop (working) drawings based on the architectural and structural design drawings of the building, (2) procure the required quantities and types of steel material, (3) arrange the facilities and manpower to fabricate and (4) work out the most suitable method to erect the pre-fabricated steelwork on site. In addition to these responsibilities is of course the need to control the construction cost of each of the above stages within budget and to ensure the subcontract can be completed in a viable business manner.

From the above scope of work, it may easily be implied that a capable and experienced steel construction company knows very well many important factors contributing to cost effectiveness of such constructions. Here the meaning of cost effectiveness does not equate only to minimum costs used, but rather to the situation where by costs spent are well balanced with the benefits given to the owner and user of the completed construction work. As some of these factors are beyond the control of the steel construction company but lying in the scope and jurisdiction of other participants in the project, namely project manager of the owners, design consultants, building contractors and steel producers/suppliers, it has to be the co-operation of all these people together that can result in cost effective steel construction. The objective of this paper is to promote such a co-operation of these people by bringing up some common factors based on our experience to their attention and arousing their interest towards achieving this mutually beneficial result. The factors listed below are by no means exhaustive but serving as starting points of more detailed discussion among practitioners, and hopefully of some systematic study in future.

II. Design

Assuming the layout of a building structure using steel construction has to be based on an overall architectural/building design which is already pre-determined, and the structural analysis has been carefully completed, the subsequent design of the steel structure can become the first step in achieving cost effectiveness by taking the following factors into consideration.

Choice of Material

The market price of raw steel material generally increases in the following order: plates, profiles, open sections, circular hollow sections, rectangular/square hollow sections; Steel of sub-grade A, B or C is readily available from steel manufacturers or suppliers. Steel of higher sub-grades e.g. DD, EE, etc. is generally more expensive and has a longer delivery time. Material of additional thickness e.g. plates over 40 mm thick, hollow sections over 16 mm thick, is generally more expensive.

Choice of Connection Details

During design of connections, if consideration can be given to the relationship between joint layout and method of production e.g. working clearance allowed between members and stiffeners, amount of joint preparation work needed, welding method that can be used, etc. then the fabrication cost of sub-assembled work can be greatly reduced.

The types of connection to be used also affect the efficiency and labour cost in the erection stage. A well planned connection scheme using appropriate weld joints and bolt joints will definitely result in cost effective erection on site. Our experience shows that the steel construction company is in a better position to choose and design connection details due to its more in-depth knowledge of fabrication and erection processes. Some design consultants are aware of this point and are able to utilize the steel construction company's expertise by assigning this part of the design work to the contractor in the contract specification. A good example of this joint effort in designing is the construction of the large span roofs for the Sports Hall and Main Hall of the Hong Kong University of Science and Technology (Total weight about 500 Tons). Here the structural consultant designed the members of the 42 m length space truss while the steel construction contractor completed all design for connections (many are in 3 – dimensional form). The roofs were completed in record time with cost saving and the steel construction contractor received a special bonus from the main contractor.

Choice of Surface Protection Coating

Normally a good painting system on grit-blasted surface is cost effective when the steel structure is protected from the weather and maintenance access is available e.g. a steel truss frame under a proprietary metal roofing system provided with maintenance catwalks. Otherwise hot-dip galvanizing with proper paint coating is preferred to ensure it has a minimum of say 20 years maintenance free period.

III. Fabrication

The way to achieve cost effectiveness in this stage depends very much on the quality of management and the production facilities in the steel construction company. Good planning and control minimizes wastage and the amount of re-work. The use of semi-automatic or automatic cutting and welding equipment is more cost effective because of its higher efficiency and of a better assurance of satisfactory work quality.

Avoid the use of radiographic non-destructive testing for weld joints as the safety measures associated with the use of radioactive instruments can cause disruption to the normal workshop operation and increase idling time in the fabrication process.

In addition to better welding equipment and methods, the amount of weld testing can be reduced. The project structural engineer can choose only critical areas to test instead of sticking to an arbitrarily fixed percentage of sample testing. Again cost can be saved without sacrificing quality.

IV. Erection

As is the case with all site activities, the building contractor has the management responsibility on site and therefore the biggest influence on how the erection of the steel structure can be carried out. This does not mean that the building contractor actually determines the method and efficiency/effectiveness of the erection, but rather it determines the constraints that will be imposed on the steel construction contractor through its planning and programme. In congested site conditions so common in Hong Kong, all other building works on site will cause obstruction to the erection of the steel structure. In turn this affects directly the extent of false work required, the types of lifting equipment to be used, the work sequence, safety and speed, and hence the cost of erection. If the building contractor works closely together with the steel construction contractor right at the beginning of its planning and programming, these constraints can be minimized and the total cost reduced. A good example can be seen in the construction of the sky bridge at the Gateway II project. A 520-ton steel bridge had to be erected at the 11/F and 12/F between two office towers. By planning in advance for this erection, the building structural members at the 12/F were so prepared during concrete casting as to enable very heavy hoisting equipment be temporarily mounted on these members and be used to lift up the bridge trusses from ground level to 11/F. This erection method in lieu of the original designed hydraulic jacking method was found to be many times less expensive and less time consuming considering the extremely big jacking height above ground to reach the final position of the sky bridge.

V. Conclusion

Our earlier statement that it has to be good co-operation among all participants in a project to achieve cost-effective steel construction is clearly supported by the above list of factors. During real life construction projects co-operation is related to the contractual arrangements in use because ultimately all parties involved will have to fulfill the obligation and duties under their own contracts. Our experience indicates that if steel construction work is placed under a nominated subcontract, as is the usual case in other specialist construction work, co-operation is more likely to happen. Firstly a capable steel construction contractor can be chosen by the owner at the earliest possible stage i.e when structural drawings are ready thus paving the way for good planning. Secondly direct communication between design consultants and the steel construction contractor is permitted facilitating discussions among all the people who actually do the final design and planning work. Thirdly, any cost saving achieved by the steel construction contractor through better design, planning, control etc. goes back to the owner directly as the tender is called and contract awarded by the owner himself or his representatives. Our suggestion here is also one easy but effective way to achieve "Partnering", the ideal working relationship which the entire Construction Industry in Hong Kong is now eagerly seeking for.

Opinions

Qualification of welded steel fabricators and erectors

by Dr. W.T. Chan.
email: wtc@quamnet.com

Structural steel is very often used in the construction of high-rise buildings and long-span structures, structural alteration and additional works, and the like. In general, the use of structural steel favours the fast track construction method as compared to the use of conventional reinforced concrete.

With reference to the structural integrity of welding work, it depends not only on the technical design aspects but also on the workmanship, which is justified with quality assurance via testing.

In local practice, the fabrication and erection of structural steelworks is carried out by the Registered General Building Contractors (RGBC), while there is yet any requirement on the qualification of the welded steel fabricators and erectors. Neither is there any stipulated requirement on the appointment of a qualified and competent welding inspector, who inspects the workmanship and the quality of welding works.

The quality of works in welding depends on the skill of the welder to a high degree. The ability of the welder to follow verbal or written instructions and testing of his skills are therefore important factors in ensuring the quality of the welding work. As standing practice, a test weld is used to approve a welding procedure as well as a welder. The credibility of such test approval can be explicitly gained by means of witness through an independent institute or a testing body, which is delegated with relevant authority from internationally recognized welding institutes.

While the Registered Structural Engineer (RSE) of a project is responsible for the structural design and construction of the project, it is highly recommended that the RSE should ensure the welder and the welding inspector to possess appropriate recognized welder approval certificates and recognized qualifications issued by internationally recognized welding institutes. These internationally recognized institutes may delegate relevant authority to local renowned engineering institutes to carry out witness for the welder and the welding inspector before the welder approval certificates and recognized qualification can be issued or renewed. By this, the standards of welders and welding inspectors will be regulated to acceptable standards, and thus the workmanship and quality of structural steel welding work can be maintained.

Call for membership

HKISC is a non-profit making organisation to promote the healthy development of quality and competitive steel related structures.

Anyone interested in steel construction, or receiving information on local and overseas technologies, and seminars or who may like to make a contribution to the healthy development of steel construction by publishing their work in this bulletin and to share knowledge with HKISC members are welcome to join the HKISC. Please download the membership application form from the following institute's web-site.
http://www.geocities.com/hongkongsteel/

Membership fee

Fellow member HK$400 per year
Corporate member HK$200 per year
Associate member HK$100 per year
Further information can be sought from

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Calendar for conferences and meetings related to steel construction in Hong Kong

3rd International Conference on Advances in Steel Structures (ICASS'02), 9-11 December 2002, Hong Kong,
organised by the
Department of Civil and Structural Engineering, Hong Kong Polytechnic University,
Hung Hom, Kowloon, Hong Kong,
sponsored by
The Hong Kong Institution of Engineers, The Hong Kong Institute of Steel Construction.
http://www.cse.polyu.edu.hk/seminar/icass02.htm

Short course

DESIGN OF STEEL STRUCTURES TO BS5950 by Professors D.A. Nethercot (I.C., U.K.) and S. L. Chan (HKPolyU), Drs. C. Gibbons (Arup) and K.F. Chung (HKPolyU)
17-19 January 2002, organised by Department of Civil and Structural Engineering, Hong Kong Polytechnic University

Please refer to Institute web-site for more conferences and seminars

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