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Avoiding failures of another kind

Satish Desai

Failure, collapse and crash are emotive terms for structural engineers, who have been trained in incorporation of safety provisions intended to avoid deterioration of concrete members and large-scale damage in buildings. Some engineers may have been curious about these terms, which have been used in reports on the recent events in financial markets in the West, especially in the UK and the USA. Engineering and financial dealings are commonly perceived as different. Engineering is traditionally related to material bodies and financial dealings are associated with human organisations. However, many modern engineering design procedures involve awareness of causes affecting human behaviour and reactions. For example, efficient stewarding and management of movements of spectators are important considerations in design of grandstands. There are encouraging signs to suggest that different professions and disciplines are coming closer together, and recognising common grounds between their individual operations. Such change in attitude may strengthen team-working and improve understanding between accountants, administrators and building professionals. With this background, it should be interesting to consider the recent financial world events, their causes and solutions from an engineer's point of view.

Developing models

Concrete is perhaps an ideal material to model different societies. It is heterogeneous and has constituents that produce a sound microstructure, if the "mix" is right and if it is "placed" and "cured" properly, just like a

society formed of mutually compatible people, well integrated and well-educated. Concrete technology has developed over centuries with mistakes made a few times, resulting in distress to the construction, just as the society has suffered from some crashes in the economy occasionally.

"Economy" could be treated as analogous to a medium supporting loading and the loading would be analogous to the "necessities" of life. The first and the simplest model could be a block of solid rock comprising a single constituent. This simple model would have been suitable for individual hunters and gatherers living in caves. Their lives were independent to start with and relied, on day-to-day basis, on their success in meeting their needs in a limited and local environment.

Further development would have led to forming units or conglomerates of interdependent constituents, for example farmers, builders and miners. Such

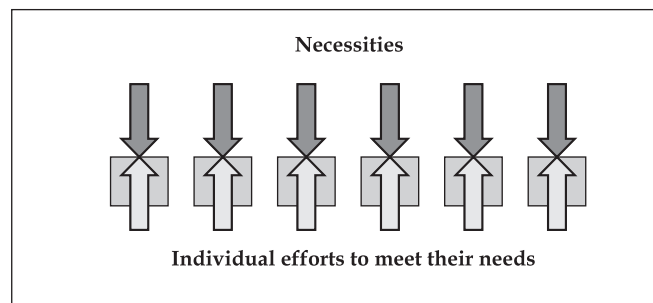


Figure 1. Simple model of economy

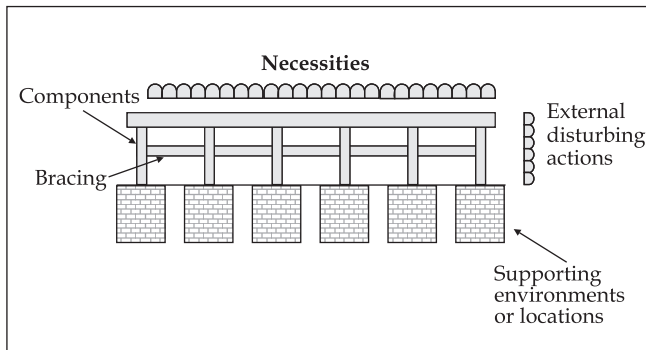


Figure 2. A developed model of society

constituents would have been drawn from the original and natural “rock”, just as the constituents of concrete are, that is cement, sand and stones. These constituents would combine in making up a unit, like a plain concrete member, that could be durable and that could maintain its integrity in transferring direct forces as the earlier block of rock did. However, it would have an inherent weakness in tension. If such a block were to “span” between supports, instead of resting on its limited and local environment, excessive tension would develop among its constituents and it would crack. This is analogous to “bridging” gaps between locations or environments that provide sustenance to different people. This difficulty could be overcome by providing reinforcement that could be analogous to such special systems as armies, police and judiciary. The constituents of a well-constructed unit would provide a dense microstructure that would bond and protect the reinforcement, just as a well-formed society would enable the special systems to work correctly.

A combination of such units would make up a frame, which would have to bear “disturbing actions”. (Action is Eurospeak technical expression equivalent to loading.) Structural engineers have to account for wind or seismic actions, as well as the gravity actions. In the financial world, “necessities” would be analogous to gravity actions and natural disasters (conflicts, storms, famines) might be considered as external disturbing actions. These circumstances would transform the local environments into States as systems for providing safety services; for example management of the infrastructure and fiscal management. Also, the components would have to be “braced” with transverse members (such as culture and language), similar to the bracings in columns of a building frame or a tower. With such qualities, a system would become a robust one that could resist disturbing forces and compensate for minor weakness in one of its components.

An important further development would be banking, or financial institutions, analogous to shear walls or strong cores in buildings. These institutions were initially meant to take in some extra capacity (saving) from some members and provide “loans” to shore up temporary shortcomings in other members. These institutions would also resist the external disturbing forces, just as the strong cores do for buildings. However, there are some undesirable changes in the societies and certain financial institutions, which could produce “internal disturbing forces” and result in potential weakening of the system. In structural frames, this is analogous to weakening of ill-protected and vulnerable members due to deterioration caused by chemical attack. A reinforcement concrete member must be made with good quality concrete and sound microstructure, to resist effectively any ingress of chemicals. Otherwise, it would suffer from cracking and reinforcement corrosion, because of carbonation, chloride diffusion, sulphate attack and alkali-silica reaction.

The distress to a structure may also result from “differential” movement in the supporting location or the environment, resulting from deterioration of the substructure and soil underneath, which would risk its stability. In the past, the stabilizing role has been directly performed by the State and the nationalised banks, by providing support to various industries in distress. (This is still the case in some parts of the world.) Such arrangement is analogous to “underpinning” the foundation to reinstate the structural stability. Provision of a “raft”, in place of individual footings, would be analogous to a federation of States, a much stronger supporting medium to overcome any local weakness.

Dr. Vince Cable’s book is entitled “The Storm”.¹ The book brilliantly describes distress to the financial market systems, arising from the disturbing actions. It would appear, however, that the world economic crisis was caused by internal disturbing actions (for example debts, risky borrowing, and financial greed), and not by the external ones (for example wars and famines) that are analogous to the heavy wind forces as implied by the title “The Storm”.

Developments in financial and structural models

Saving and spending

An established population would be made of different professions, for example farmers, miners, builders and product manufacturers. These people would use their skills to produce goods for the use of the population or for the export trade. There would also be educational

institutions where teachers would train the future generations to provide them with a basis essential for their development as members of the society. All these people would earn and look after their families. These families may have some surplus capacity after paying the State for provision of public services, which would be spent in many ways, for example savings for the future, giving to charities. Most people would have bank accounts for receiving their salaries and paying their dues.

With the changing world, in the West, attitudes towards savings have changed. Saving for the future was a good idea in the past and it provided safety from unforeseeable circumstances in the future. Now saving is of secondary importance for some people in the West, overtaken by the urge to spend. Additionally, an anti-state philosophy would mean that the individuals are supposed to be better able to decide about how to spend their income and they should pay less and less taxes to the State.

Safety of structures

A model society would compare with a structure where all members complement one another to provide stability and robustness to the frame. Against normal actions, they would have some extra capacity offered by factors of safety, for example some reserve strength, such as saving in financial sense, to provide defence against abnormal and unforeseeable actions. In structural design procedures, such factors are meant to safeguard from errors in assessment of actions or in design models, as well as dimensional inaccuracies.

An unfavourable attitude towards saving has a parallel in structural engineering, in the form of a movement towards reduction in factors of safety. It is alleged that this is promoted by the industry bodies to make their products more economical. However, such initiatives do promote sustainable construction, through rigorous design (avoiding overdesign) and reducing the member sizes and, thus, saving in construction materials. All the same, modern design procedures should essentially have safety of construction as the priority and any such advancement in structural design should be matched by necessary improvement in construction skills.

Safety and use of new products and structural concrete

In concrete technology, new products have been introduced for making concrete, for example, industrial by-products like pulverised fuel ash (PFA) and ground granulated blast furnace slag (GGBS). This development does promote sustainable construction, and quality of concrete could improve with extra care and efficient

mix design, but the use of such products has to be made with extra caution. This is similar to the advantages of careful assimilation of new people and industries into a society.

PFA has slow development of strength, which would result in delay in formwork striking time. PFA concrete could have increased setting time and, so, plastic shrinkage may increase. This may lead to cracking unless early curing is provided.

GGBS concrete would also have slower early age strength development, especially with higher cement replacement level. Special mix design and attention to curing is needed for concreting thin slabs in cold weather. GGBS concrete could develop early strength but *minimum of six days of water-curing* is essential for long-term strength development. Water-curing has to be clearly specified in building works contracts, if GGBS concrete has to be used. Without water-curing, 91 days strength of in situ concrete could be only about 60 or 70% of the 28 days standard control strength.

Recycled concrete aggregate (RCA) can be safely used to replace natural aggregate to the extent of 30%, in low performance applications (for example pavements and internal RC members) However such RCA has to be chemically inert. Besides, use of RCA requires special attention where the design includes consideration of creep and shrinkage.

Complexity arising out of interconnected units

Structural engineers are often required to deal with an assembly of structures and find solutions to ensure that differences between the behaviour of individual frameworks would not jeopardise the stability of the

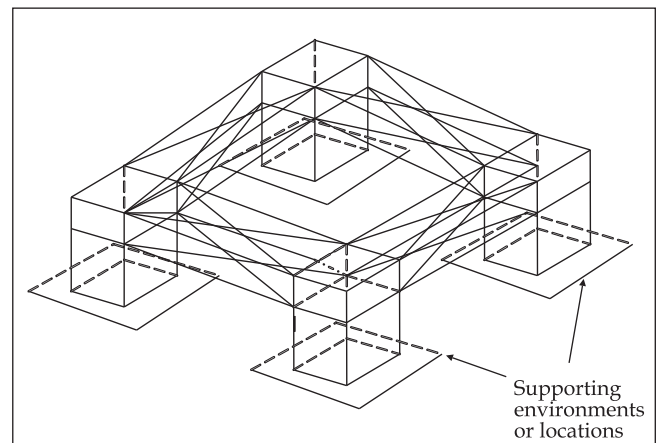


Figure 3. Complex interlinked structures with diverse supporting environments

assembly. The problem is made many times more difficult when dealing with interconnected structures with separate foundations supported on strata with dissimilar characteristics, that is compressibility, shrinkability or volume change with varying moisture content. These structures may also be subjected to different actions and adverse influence of dissimilar supporting systems. Such complex of interlinked structures would suffer from indeterminate internal distress.

Because of advancement in information technology and growth in multinational enterprises, individual national economies have become linked. This process of globalisation has gathered speed, despite the economies being dissimilar in nature, for example with wide cultural differences as regards lifestyle and attitude of some people to spending, saving and borrowing. Recent difficulties in the financial markets have some similarity with the structural problems, especially the attack of internal disturbing actions arising from greed and excessive risk-taking by some financial institutions. The distress suffered by financial markets has been exacerbated by their entanglement and the fact that they do not operate within national frontiers.¹

The emerging economies like China have a workforce that is highly motivated and traditionally inclined to save money. China also has an estimated foreign exchange reserve worth \$1.8 trillion, because of the exports substantially exceeding the imports. China has invested the surpluses in buying bonds in the USA, which has aided the US financial institutions to provide loans to such customers as would like to borrow and not save. The oil producers also have similar surplus funds that have gone into the US economy. Even after the credit crunch, it is worrying Americans that they would have to depend on Middle Eastern and Asian sovereign wealth funds to recapitalise their battered financial institutions.

There are international organisations such as the World Trade Organization (WTO), and World Bank and International Monetary Fund (IMF). However, their influence is not enough for relieving problems of financial institutions. The WTO has difficulties attributable to differences between policies of countries on such issues as international tariffs, workers' rights in China, and the USA and European reluctance to offer enough concessions in liberalizing agricultural trade. WTO influence may weaken further with increasing tendency among countries to opt for regional and bilateral agreements, which will in its turn weaken the fragile connections providing some governance for the world economy. The IMF role is limited to providing

balance of payments assistance to small and poor countries. Its earlier central role in easing temporary payments crises of countries has become peripheral. The countries have instead piled up large currency reserves as a safeguard, which is a wasteful alternative. In conclusion, the WTO and IMF links are not strong enough to serve as effective bracings to provide stability for the interconnected assembly.

Diversities of response to external actions between the interconnected units would create tensions and excessive instabilities in the assembly. This is analogous to differential settlement between units, if one were to have sounder structure and more unyielding environment or foundation than the other. The assembly may not collapse, provided the unit subjected to distress were to be "underpinned" and its members were strengthened in good-time. This may mean, in financial terms, providing liquidity to banks, promoting changes in borrowing habits and clamping down risk-taking of unsafe proportions.

Internal disturbing forces

Building safety issues

Basis of structural concrete design

Structural engineers are expected to have affinity towards sciences (Physics, Chemistry and Mathematics) and they should undergo training to develop experience and sound judgement during their formative years. Engineers use these skills to design and construct buildings based on tried and tested principles. Risks are not taken without any thorough and rigorous analysis. Measures can also be introduced to afford protection against any potential worsening, for example special mix design for concrete. Project-specific rigorous analyses are used for designing specialist projects, for example bridges and strategic buildings like nuclear power stations.

Concrete is a versatile and widely used material. However, making of concrete suffers from over familiarity and it is treated as a low-technology material in common building construction. The most important point is that it has to be correctly mixed and placed to achieve its potential for durability and strength. While it is not conceivable to go back to the days of pure Portland Cement (PC) concrete and 1:2:4 concrete, properties of constituents and their compatibility has to be fully understood. In older concrete construction, there were three constituents – cement, sand and stones. If we were to use blended cements and RCA, the complexity would increase, perhaps exponentially, with the increased number of constituents. The problem could be analogous

to ingress of new members in a society and difficulties encountered with their assimilation into the existing system.

Deterioration of concrete structure can result from badly made and placed concrete, in the form of disturbing actions such as carbonation, chloride attack, sulphate attack and alkali aggregate reaction. Common solution is to ensure sound microstructure and alkaline environment to prevent rusting of reinforcement. Special mix designs are required to cope with individual aggressive environment.² In a general sense, use of bad concrete must be avoided with supervision and suitable building control. Properly designed concrete structures can withstand such actions as wind and earthquake, provided the quality of concrete construction is sound. Without such precautions, failures can occur and image of concrete construction can suffer.³

Causes on quality of design and construction of buildings

Sir Terry Leahy, the chief executive of Tesco, has described the standards of state school education in the UK as "woeful". For engineering students, it is essential to have good standard of knowledge in Physics, Chemistry and Mathematics. Otherwise, academic standards of engineering graduates could suffer and present problems in their development as designers of structures. Also, standards of checking of designs and site supervision appear to be declining. It is unfortunate there is no real incentive for sufficient structural engineering participation in the Building Control process and the level of site supervision by Building Control Officers is questionable.

The situation is made worse in the UK, with the proliferation of "Design and Build" projects and the facility to start work with an "Initial Notice", to help fast-track construction and profit-orientated management and execution of contracts. A Building Control Body is often presented with "Early Stage Design" and "Tender Stage" drawings. These procedures are all well-intentioned but they invariably jeopardise adequate and independent examination of the final structural details and any real control on their incorporation in the works.

There is significant dissatisfaction with the state of new housing in the UK, as cited by Terry Williams in his report compiled in 2006, which utilises the data from a finite sample of snagging surveys.⁴ This report has revealed distinct lack of care and diligence by participants in the new home construction and inspection, in keeping quality standards and improving

quality performance. It is disturbing to note that 18% of the cases could bring building integrity into danger, with 78% showing aesthetic dilapidation and 4% showing health and safety at risk. Such defects would jeopardise the ability of a building to last for its expected service life, without any need for premature and excessive maintenance activities.

The report concludes that the existing control systems and policies for quality and consumer protection within the UK new house-building industry are not effective. Such erosion of good practices could lead to increasing internal distress in the building industry and it could result in failures in the future, unless some changes are implemented for reversing the trend.

Financial market issues

While there are rules about conducting banking and financial operations, there are some rule breakers gifted with skills to evade them. Breaking of rules is mainly driven by an urge to increase profits and taking unjustifiable risks. Such risk-taking would endanger stability of the markets. Market crashes have happened a few times in the past, including the great depression in 1930s that had a traumatic effect worldwide. At the end of each crisis, some palliative measures have been taken, which have not had any long-term effectiveness. It remains a truth that the financial crashes and economic cycles are closely related and have continued, and they may have become untenable for regulatory measures to be effective with the advent of globalisation. This may not accord with structural engineers, who are trained to seek solutions that should work and reduce risks presented by internal deteriorating mechanisms.

Crashing of financial markets in the USA and its worldwide impact

The American mortgage market was worth some \$12 trillion in July 2008, nearly five times that in the UK.¹ Part of the amount, \$5.2 trillion, was acquired and effectively guaranteed (or so it was assumed then) by two privately owned and State-backed agencies; Federal Home Loan Mortgage Corporation (Freddie Mac) and Federal National Mortgage Association (Fannie Mae). Fannie Mae was the first agency, intended to stabilise mortgage lending and stimulate the housing industry. It was privatized in 1968, to finance the Vietnam War, and its explicit guarantee was dropped. Freddie Mac was set up as a competitor.

Both Freddie Mac and Fannie Mae would buy and sell mortgages of limited value (about \$400,000) but not be directly involved in the sub prime mortgage market,

whereby loans were given without ensuring that the borrowers could repay. Although the sub-prime mortgages were left to the fully private sector banks, Freddie Mac and Fannie Mae had some mortgages with marginal risks and they held large amounts of securities backed by sub prime mortgages, which exposed them indirectly to the risks associated with that market. Freddie Mac and Fannie Mae, and the banks, sought to sell on the mortgage debt in the form of mortgage-backed securities, a process known as securitisation which broadened out into slicing and dicing of the risks, thus diluting the risks. However, the initial debt was "leveraged" and made larger and larger as the leveraging progressed further. Each transaction would produce a margin of profit for the investment fund, shared by the brokers, dealers, managers, shareholders.

The overall effect was astronomical amplification of the original debt. This was further complicated when the institutions borrowed money to buy debt, which was the security for borrowing, and the money that was borrowed was in its turn borrowed! In addition, debt default could be insured and the insurance companies depended on borrowed capital. Another instrument was introduced as Credit Default Swap (CDS), which would allow the investor to pay for and separate out the risk of non-repayment by the borrower. The CDS market grew on the back of the growth of all the other debt instruments to a notional value of \$60 trillion. In the end, no one really owned the loan!

Many sub prime mortgages had low interest rates for the first 1 or 2 years. In 2007, the USA had to increase interest rates because of inflation. This made mortgage repayments more expensive. And, many homeowners, who had taken out mortgages 2 years earlier, now faced far higher rates of payments as their introductory period ended. Simultaneously, their disposable income was lowered because of rising health care costs, rising petrol prices and rising food prices. This caused a rise in mortgage defaults, as many new homeowners could not afford mortgage payments. These defaults also signalled the end of the US housing boom. US house prices started to fall and this caused more mortgage problems. For example, people with 100% mortgages now faced negative equity. It also meant the loans were no longer secured. If people did default, the bank couldn't guarantee to recoup the initial loan.

By February 2007, the number of defaults increased to such proportions that many US mortgage companies and sub prime lenders were reporting unbearable losses and filing for bankruptcy. This was a fuse that appeared to light the explosive of amplified non-traditional lending

outside the banking system. In the event, the first large bank to default on its debts was Lehman Brothers. The subsidence was setting in with such ferocity that it took in many national and international banks. All these banks had supposedly safe investments but they were exposed to bonds backed by sub prime mortgage debts. Even the German banks and UK banks like the Royal Bank of Scotland were crippled with heavy losses. The result was that, all around the world, it became difficult to raise funds and borrow money. The cost of interbank lending was increased significantly. Often it was difficult to borrow any money at all. Customers lost confidence in banks and started withdrawing funds, which further exacerbated the crisis.

Potential crisis in Japan

Besides the countries in the West, Japan could face a problem that has its roots in the year 1999 or immediately after the Asian financial meltdown. This is believed to be the result of flawed government policy, whereby the state housing loan agency offered mortgages to families that they knew were unable to pay. These loans were made on the assumption that the traditional strong points of Japanese corporate life would stay for ever, that is seniority-based pay increases, constantly rising bonuses and lifetime employment. The impending meltdown could affect some hundreds of thousands of households and it will be focused initially on the country's industrial heartlands, where corporate bankruptcy rates are rising.

After-effects of the credit crunch

Introduction of rules and new practices

Similar to any review of structural regulations after an unfortunate incident, financial markets and the governments are coming around to review the situations. In the UK, the Financial Services Authority (FSA) has rules and supporting code for remuneration practices. This code calls for an end to the practices such as awarding bonuses to star performers in financial institutions. It is further envisaged that substantial proportions of bonuses should be deferred, possibly paid in the form of shares and subject to claw-back. Foreign banks in the UK have agreed to comply voluntarily with the FSA rule on remuneration for their UK-based employees that is to consult with the FSA before settling pay policies for the senior staff. One of the changes in attitudes of bankers may lead to tying down bonuses to long-term success of the business instead of quick rewards tempting the managers to indulge in achieving gains in stock regardless of the excessively risky nature of their methods.

Other regulations are intended to create countercyclical capital buffers. For example, the banks are required to hold substantial capital, almost twice as that required earlier and this limit is set to rise even further. Besides, the banks should abide by "liquidity standards" and buy government bonds sufficient for their operations. Such requirement would restrict the lending to a sensible level, as this money will not be available for lending to customers. Because of the credit crunch, mortgages have become more expensive in the UK and risky mortgage products like 125% mortgages have been removed from the market.

Long-term effects

According to the report in a leading British newspaper ("The Independent" of 15 October), the recent credit crunch has meant 7 million job losses and 2 million home foreclosures in the USA alone. All over the world, businesses and consumers are still struggling to get finances. The markets dried up and the governments had to step in and increase their own borrowing to recapitalise the banks and guarantee saving deposits. The current IMF estimates show that, by 2014, government debt will reach 239% of GDP in Japan, 132% in Italy, 112% in the US, and 99.7% in the UK. The UK would have a serious problem, as the debt has more than doubled compared to the 2007 level of 44%. It may mean that the credit rating of the UK government bonds may have been downgraded and it could become more costly for the government to raise money.

Governments in rich countries have spent nearly \$10 trillion to support the financial sector. This sum has enabled capital injection (\$1.1 trillion), purchase of assets (\$1.9 trillion), guarantees (\$4.6 trillion) and liquidity provision (\$2.5 trillion). About \$1.9 trillion represents up-front expenditure, while the rest is made up of guarantees and loans. These governments are likely to recover most of these sums when the world economy recovers, but big deficits will stay and public finances could suffer from long-term damage. The net after-effect of the credit crunch may continue to be felt for a long-time.

For an engineer, this scenario would compare with a massive repair and underpinning exercise to avoid collapse of a large and tall building. Such building would have had badly protected elements exposed to severe deterioration. It would also have been in danger of subsidence, without sound foundation based on proper soil investigation to check out any presence of soft soils or cavities or mine shafts deep under the proposed site!

Concluding remarks

It appears that the credit crunch has weakened the world financial markets, particularly in the West, but their collapse has been avoided through government measures. There may be a long-term distress but recovery is the only alternative, however slow it may be. France and Germany are out of recession and the UK is also on the path towards recovery. It remains to be seen whether there are changes in lifestyle in the West, and savings and prudence can replace tendencies to overspend and indulge in excessive risk-taking in financial matters. In the East, countries like China may aim at improving living standards of the workers and encourage their workforce to spend. This may reduce imbalance of trade between China and the West and foreign exchange surplus in China. The USA has succeeded in reducing its dependence on imported fuel and such continuing trend may reduce intake of surplus oil money into the USA. These developments may indirectly reduce borrowing habits in the USA, resulting from reduced influx of foreign funds.

In concrete technology, making and placing concrete could be improved with awareness of the users regarding optimum choice of constituents. Structural engineers could be well trained to provide measures against large-scale collapse resulting from a local accident. Standards of education in science subjects could improve the general standard of design, checking and construction. Otherwise, proliferation of internal disturbing forces like deficiencies in design and construction could result in unfortunate failures of buildings.

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Prof. Satish B. Desai, BE, PhD, FStructE, recipient of the 'Officer of the Order of the British Empire' (OBE), has over forty years of experience in civil engineering (design, construction and project management), building regulations, codes of practice, guidance documents, research and research management. He has authored more than 45 technical papers on reinforced concrete, published around the world. He is an honorary visiting professor and a member of the Industrial Advisory Board at Kingston University, Surrey, UK.