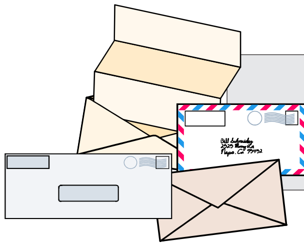

# Letters to the Editor

## Special Issue on IS 456 : 2000

This has reference to the articles in the IS 456 : 2000 special issue of *The Indian Concrete Journal* published in February 2001.

Efficient utilisation of materials and improvement of safety and quality of the product made out of them are the basic objectives behind the preparation or revision of a code pertaining to the subject product. The present revision of IS 456 after 22 years of deliberation to reconcile and rationalise the needs and aspirations of users having widely different expectations and demands and to bring the exercise in line with accumulated knowledge worldwide and wisdom in the field, is a laudable attempt. Such a synthesis can never be perfect and *The Indian Concrete Journal* has done a yeoman's service in bringing out an issue devoted exclusively to a close study of provisions of this revised code. It cannot be denied that the IS 456 is the most widely used code in the country and seeks to serve all kinds of users; engineers, technologists, designers, manufacturers of the constituents and accessories, technicians, builders, developers and entrepreneurs engaged in the industry of concrete construction constituting the major share of the country's development budget. No doubt, the code is perceived to be having some shortcomings which should be deliberated in detail by BIS and the concerned amendments should be issued fast as the country seeks to be on a fast track to regain the time lost in the slow pace of last 50 years.

(*i*) The Guest Editor has rightly pointed out that emphasis on concrete cover without due regard to the grade of concrete would affect substantially large sizes of members even in normal environment. Simple elements like lintels and chajjas on external walls and slabs in bath and kitchen would qualify for a moderate exposure environment needing a 30 mm cover and a higher grade of concrete, that is, M 25, than M 20 concrete in a mild environment. The 15 mm cover for inside slab, quite common so far, has been retained only for a slab, in such an environment with 12 mm diameter steel, (*Table* 16 of the code). But this also will not be acceptable as the fire rating for a slab would need a minimum 20 mm cover for a maximum rating up to 1 hour – a bare minimum for any exposed structure, (*Table* 16A). In other words, the popular 100-105 mm thick slab with 15 mm clear cover will now have to be minimum 105-110 mm thick even though it has typically a floor finish of 15 mm to 20 mm on top and a 6 mm to 10 mm plaster on its bottom. There is thus clearly a case of reducing this 20 mm minimum fire cover by 5 mm or so, as in durability requirement for slabs not directly exposed to fire (being covered by flooring or plasters) or protected by a fire retardant paint of minimum one hour rating on its exposed face. This will also make 75 mm thick slab more acceptable as shown in *Fig* 1 of the code. Incidentally, good quality fire retardant paints are available in the country and can be given due consideration.

Further, durability is directly related to the permeability of the cover concrete, rather than the concrete of the structure. Sufficient data are now available regarding the permeability of normal concrete of different grades. These can be regarding permeability against water, air (carbonation/ oxygen) or chlorides, the latter being relevant for severe to extreme categories of exposure. For covers above 35-40 mm, protection against spalling is also required at an additional expenditure. Hence, for such categories, it will be more scientific to specify the maximum permeability range acceptable through the cover and design its thickness accordingly with regard to the grade adopted. It will also encourage alternate durability measures other than increasing the cover thickness; for example, application of suitable coating on the concrete surface or directly on steel like fusion bonded epoxy, using silica fume or fibre mesh in cover concrete and so on, so as to obtain the specified degree of impermeability.

In case of marine structures or inaccessible buried concrete in an aggressive environment, where chloride permeability is an important factor of corrosion, coating reinforcement steel is also a preferred option with a medium size cover depth – say 50 mm. Concrete of practically zero impermeability (against water) has reportedly been obtained with the use of silica fume (up to 10 percent and above by weight of cement) and superplasticiser. As the cost of silica fume is at least five times that of OPC, the product along with superplasticiser will make the concrete some 10 percent costlier than OPC apart from the stringent need of early prolonged curing in a controlled environment. Hence, some reduction in cover depth can be admissible without lowering the durability level, by adopting either of these two measures (rebar coating/using silica fume in concrete) amongst the few alternatives available.

(*ii*) Dr C. Rajkumar in his paper titled "Provisions for cements and mineral admixtures" on pp. 105-112 has rightly opined, "compared to flyash silica fume is much more reactive". In *Table* 4 given in his paper, microsilica has a pozzolanic reactivity of only 427, as against 875 of flyash and 1050 of metakaolin. Assuming that silica fume and microsilica are the same, it seems by "reactivity" he means fast reaction with cement hydration products leading to an early completion of this chemical activity whereas pozzolanic is a slow and long-term activity leading to gradual gaining of strength and other mechanical properties over a period of 3 to 12 months. He may throw more light on these two types of reactivity.

He has rightly pointed out that water-cement ratio should actually be the effective water-cement ratio and the minimum cement content '*C*' can be replaced by '*C*+KF', where *F* is the supplementary cementing material–SCM–(flyash in this case) and *K* is a co-efficient depending on the activity of SCM. '*K*' of flyash has been given as 0.3 to 0.8. It will be interesting to know the value of *K* for other pozzolanas—microsilica, metakaolin, etc. In fact, the mix design for blended concrete should use such expression of '*C+KF* ' instead of plain '*C+F* ' and the present code may give the '*K*' values of such activities as well.

(*iii*) Mr S. A. Reddi in his paper titled "Section 2 – An overview" on pp. 114-119 has explained the rationale behind non-inclusion of IS 10262 – "*Recommended guidelines for concrete mix design*" in the list of referred Indian Standards. Whereas his contention may be justified for high performance concrete, special concrete for specific projects and big projects having dedicated quality control and quality assurance teams for mix design and manufacture, this is not so for bulk of the concrete work across the length and breadth of the country done for housing and ordinary structures where one–shot mix design and quality control of the mix strength by simple cube testing are the norms of the trade. In fact, some of us in this megacity will be lucky if the concrete of our tenements have been really blessed by this degree of minimal quality assurance, though many of the builders do flaunt ISO certification. They however all, use standard cements – ordinary or blended—of reputed companies and do not do any blending at the site. It will be thus extremely useful if IS 10262 could be revised and issued by BIS soon for reference by the users of the present code. *Table* 8 of the revised code has already provided for increased standard deviation for common grades of concrete with limited quality control (for example, 5 $N/mm^2$ for M 20 and M 25, 4.5 $N/mm^2$ for M 15) and the design strength of the mix can be accordingly worked out, which can be practically achieved with a fair level of quality control.

The present code has also increased the limit of domestic chloride in concrete at the time of placement, keeping in view the state of constituent materials and site conditions in the country. As all this is acid–soluble chloride, this along with similar chloride diffused or entered through cracks from the external environment, will corrode the reinforcement easily if the pH value of the concrete around the steel falls below 12.5 (for allowable domestic limit of 0.6 $kg/m^3$) or 12.2 (for a limit of 0.4 $kg/m^3$). For the usual chloride content of around 1.2 $kg/m^3$ during the life in a chloride–laden environment, the threshold pH is 13, which is even above the usual pH in most of the fresh concrete[1]. Even in a sulphate – ridden environment, cement with low $C_3A$ reacts with chloride first, but the amount fixed will be small in view of small amount of $C_3A$ and its competing reactions with both chlorine and sulphate ions. Carbonation adds to the distress particularly in a high alkaline environment and the cover depth beyond 20 mm can be completely carbonated in normal OPC concrete – M 15 to M 20 in less than 50 years.

All these issues emphasise the imperative need to use blended cement concrete with flyash/blast furnace slag with or without silica fume which reduces permeability as well as diffusibility substantially to fluids, laid with adequate cover – well compacted and cured with a minimum cement content. It also draws attention to the fact that the threshold level of pH for chloride corrosion is quite high and rather easily attained in a critical or strategic structure placed in an aggressive environment and subject to repeated dynamic impact, freezing and thawing or other cyclic load surcharged with reactive and damaging chemicals like chlorides, sulphates, carbonic acid, nitrous acid, etc as in marine structures, high traffic flyovers or bridges in coastal environment. This is because interactions between the several types of forces and compounds in play is too complex to quantify the effect of which is just not a summation of the effects of individual elements. Under such a holistic interplay of environment, micro cracks even in good concrete cannot be totally ruled out particularly when high early strength and highly reactive silica fume is used. There has been therefore a practice worldwide to take recourse to provide direct barrier coating to reinforcement for achieving long term durability in such a situation. A service life of 75 years or more for bridges is the goal of builders now-a-days and corrosion experts also speak of redundant corrosion–protection systems to achieve satisfactory long term performance[2]. Using a coating like fusion bonded epoxy coating (FBEC) along with all other codal provisions for good concrete in the environment in which it is placed is an example of such a corrosion–protection system.

In fact, the Ministry of Transport of the government of India is already using this system on all bridges and flyovers in marine environment where rate of corrosion is greater than 0.25 mm for 1 year (vide their Circular No. RW/NH/34041/44/91 – S&R of 14/21.3.2000) [3]. The revised IS 456 does not say a word about protective coating in aggressive chemical environment. In clause 8.2.8.4 under Clause 8.2.8 regarding concrete in sea water, it summarily dismisses such a situation by the simple time–worn statement, - "It (protection) may be achieved by treating the surface of reinforcement with cement wash or by suitable methods." (*The word within* *bracket is mine*). This is in sharp contrast to ACI 301–96 "*Specifications for structural concrete*", which includes a provision for epoxy coated steel reinforcing bars [2, 4, 5].

(*iv*) In India, substantial works are being carried out in the western and southern regions of the country with FBEC of steel. The materials and application, technique and equipment used are now locally available backed by a stringent quality standard laid down in A775M/A775-96. The relevant Indian Standard is updated[3].

An alternative to this FBEC is silica fume. A comparative cost economic study tends to indicate no cost advantage over FBEC system by using silica fume. Mr Reddi's view in this regard will be highly welcome, particularly when in the same issue in another article; "Cement concrete and grades of concrete", he informs that the JJ Hospital flyover in Mumbai uses M 75 concrete with condensed silica fume without the need for any coating either to the reinforcement or to the concrete surface, even though the structural design is based on M 60 grade of concrete for enhanced durability because of its situation close to the sea coast. Thus, the cost comparison becomes easy for M 60 concrete with FBEC rebars as per MOST specification versus M 75 concrete with silica fume and superplasticiser.

(*v*) The discusser agrees entirely with Mr Reddi that the increase of cement content from 250 $kg/m^3$ to 300 $kg/m^3$ particularly in mild environment is a severe stipulation which increases the cost of concrete by more than 5 percent for no proven benefit and that too, in a scenario where cement quality has consistently improved in the last 22 years. This needs a serious re-look.

(*vi*) The point of view "Shortcomings in structural design provisions of IS 456 : 2000" by Dr C. V. R. Murty on pp. 150-157 raises a few important points which require a close review particularly the provisions for seismic loads. The requirement that the ductile flexure failure occurs before the undesirable ones like the brittle shear failure is met by an under-reinforced ductile design which absorbs the disturbing energy through inelastic deformation and in the event of a strong earthquake shaking develops a favourable collapse mechanism can be considered universal for any good RC structure. As IS 13920 : 1993 deals exclusively with earthquake–resistant structures, a cross reference to the said code in appropriate clauses of the present code should serve the purpose; and the IS 13920 itself can be further updated to incorporate the latest developments in this regard. The non-recognition of higher strength of concrete under confinement with a higher maximum strain than that stipulated in the revision, the downward revision of shear reinforcement near the support, absence of guidelines for the design of frame joints and non-inclusion of the capacity design concept where structures designed for a natural accidental load like a seismic event are deliberately designed for a much smaller force than that would be there if they were to remain elastic, are some of the shortcomings requiring immediate amendment, as rightly pointed out by Dr Murty. The last point has also been highlighted by Dr P.C. Basu in his paper "Observations on design provisions"– particularly the absence of shear friction provision in the code. The discusser however, does not support his suggestion for a unified code within the country for concrete with both passive and pre-stressing reinforcements, simply because most of the code users here deal with only RC; often with nominal mix concrete and a bulky volume including high performance concrete. This may create problems not only for the code makers in rationalising widely divergent needs and practices, but also for users many of whom have to be told which clause is to be used where and its interpretation in a particular case. There are codes for ductile detailing, liquid-retaining structures, earthquake-resistant structures, pre-stressed concrete and so on serving specialised needs. Let these remain but get them updated regularly on a continuing basis.


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### *Prof Dayaratnam replies :*

As I have mentioned earlier, design specifications based on the durability of concrete structures is the major change made in the IS 456 : 2000. The minimum cover to reinforcement and grade of concrete requirements either based on the exposure condition or on fire rating will be demanding more than what we had in the earlier code. This certainly effects the minimum dimensions that we are used to. Many thin elements such as slabs, poles, ribs, beams, etc, may have to by upgraded to some extent. The permeability is the most important property that affects the durability and not the fire rating. However it is not practicable to make the permeability specification for minimum cover, etc. Even though the other has a point, but what the code has specified is more practicable. Protection of the reinforcement bars is an important aspect in the durability consideration. For moderate and severe exposure conditions, it is better we stay with the minimum cover and the grade of concrete. However, in the very severe and extreme conditions of the exposure, reinforcement bar protection may become inevitable. All structures exposed to such environment need special attention by the consultant and builder. The comment made by the author is more relevant in such exposure conditions. The good suggestions are worth considering in formulating the next revision.


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***Dr Rajkumar replies:***

The author would like to thank Mr Singha Roy for pointing out the possible misinterpretation of the relative pozzolanic reactivity of flyash and silica fume. At the outset let me point out that the concrete mixes containing flyash or silica fume are two different systems and they should be considered so. Secondly, it would be more appropriate to say that silica fume is a better effective pozzolana than flyash. To clarify this as well as some of the points raised in the letter of Mr Roy, I have elaborated some of the issues.

*Reactivity of different pozzolanas:* The mineral admixtures permitted in IS 456 : 2000 belong to the type which is either pozzolanic or latent hydraulic. In the code both flyash and silica fume are considered as pozzalanic materials and designated so along with rice husk ash and metakaolin.

*Table* 4 of my paper summarises the relative reactivity of different pozzolanas as determined by the Chappelle test and presented in increasing order. The comparison is based on depletion in free lime through pozzolanic reaction. It is expressed as milligram of calcium hydroxide converted per gram of pozzolanic material. These values do not indicate rate of reaction with respect to time. As this data is related to a comparative evaluation study of high reactivity metakaolin any conclusion drawn based on this study may be restricted to show the effectiveness of metakaolin in reducing free lime content in hardened concrete.

*The effect of flyash or silica fume on the properties of concrete:* The properties of hardened concrete that are significantly influenced by the addition of pozzolanas are strength and permeability, and these in turn, influence several other properties. Addition of flyash in flyash concrete may be as high as 60 percent of OPC content and because of the high replacement level, the flyash concretes are characterised by their low early strength and high ultimate strength.

The low early strength is attributed to the partial replacement of portland cement, with a material that is not hydraulic. In such combinations the long term strength gain can be significantly high. Since the pozzolanic reaction proceeds in the presence of water, enough moisture should be available in the concrete to get the benefit of long term strength gain and decrease in water permeability. This is possible in structures immersed under water.

The high strength and the low permeability of silica fume concrete are attributed to several factors such as aggregate-cement paste interface refinement, pore refinement besides early pozzolanic reaction. Physical and chemical effects of the silica fume addition are the reasons for the enhanced characteristics of silica fume concrete. Silica fume is ultra fine powder, when it is mixed with concrete the workability of the concrete decreases. Because of this, the use of silica fume in concrete is not possible without the addition of superplasticisers.

*The K-value concept:* The denominator in the water-binder ratio is split into two terms; the mass of portland cement component, *C*, plus a factored term for other cementitious materials. This is termed as the *K*-value concept in the Draft European Standard prEN206 "*Concrete-Performance, Production and Conformity*". The *K*- value recommended in prEN206 for silica fume is 2.0. In the mix design adopted for construction of Great Belt Link, Denmark, the value of *K* is taken as 0.5 for flyash and 2.0 for silica fume. Use of this concept in the mix design procedures has certain limitations. Citing a recently published article, "How useful is the water cement ratio" published in the September 1999 issue of *Concrete International*, Prof. Neville has made an interesting observation". the value of *K* is different for, not only different flyashes, but also for different ages of concrete. By the age of several months, I would not expect any difference between flyash and portland cement."

Before the *K*-value concept is introduced in IS 456 : 2000, we require formulation of Indian Standards on different mineral admixtures recommended in the code. The actual value of *K* depends on the specific additions and these values have to be established before recommending in the code.

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***Mr Reddi replies:***

The bulk of the concrete work across the length and breadth of the country used for "housing and ordinary structures" in fact do not practice design mixes at all and as such, the question of inclusion of IS : 10262 is not relevant. The current usual practice, in such cases, is to use nominal mixes. However, Mr Roy himself admits that one-shot mix design and quality control by simple cube testing are the norms of the trade.

Mix design is not an exact science. The proportioning ultimately depends on trial mixes. At best the guidelines could be the starting point for new entrants. As such, none of the standard making bodies in the rest of the world has brought out any guidelines for mix design. IS 10262 was originally brought out at a time when only 33-grade cement was available in the country. Most of the information contained in IS 10262 are relevant to 33 grade cement only. Moreover, admixtures are now being used extensively for production of concrete. This is also not considered in the guidelines.

In view of the above, widespread experience indicates that use of IS 10262 in the present form results in highly uneconomical mixes without any corresponding benefits. Overall, these result in about 20 to 25 percent excess consumption of cement. The guidelines cannot be used in the present form. A thorough revision of the guidelines is necessary and a process has been started in order to bring the guidelines in the context of the present international practices and availability of higher-grade cements and admixtures.

Regarding chloride content in concrete, the limits specified in the present code are pragmatic and in line with the codes of developed countries. In the earlier edition, unrealistically low limits were specified which were not practicable. The present limits are much below the threshold value for initiation of corrosion. The commentator's views about the use of blended cements are well taken. However, his statement that there has been world wide practice to provide coating to reinforcement is open to question.

While the materials for FBEC are available in the country, the same is not the case in respect of the application techniques and the precautions necessary for handling and fixing the coated reinforcement bars, given the high level of manual operation in the country and the absence of a code of practice for the same. The commentator's reference to the construction practice at JJ Hospital flyover is interesting. Superplasticisers are required for both M 60 and M 75 concrete. The cement content is more or less same the higher strength is normally achieved by using lower water-cement ratio. The only additional cost pertains to silica fume. Apart from the cost of silica fume concrete structure being lower than that with epoxy coated reinforcement, there are no uncertainties in case of silica fume concrete concerning the workmanship difficulties associated with coated reinforcement.

However, FBEC can certainly be used on a selective basis for severe environmental conditions subject to stringent precautions regarding the handling and fixing of reinforcement. The present Indian standard on the subject is outdated and needs immediate revision. It may also be realised that there is substantial loss of bond between concrete and any coated reinforcement. This factor should be taken into account at the time of designing the structure.

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***Dr Murty replies:***

I thank Mr Roy for the comments. The following is my reply.

Independent of whether the structure is being designed for seismic forces or not, the ultimate behaviour of the structure should be one of "ductile flexural failure" with warning. Under reinforced design for flexure as treated in IS 456 : 2000 does not assure this, and does not say anything about the ductility of the sections/structures. The current procedure for design of RC members does not guarantee that shear failure will occur after flexure failure. Also, a mere reference to IS 13920 : 1993 will not serve the purpose, as designers dealing with "non seismic" structures may not even look at the clauses therein and hence may have a structure that has brittle shear failure occurring before the ductile under reinforced flexure failure.

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