DESIGN OF INSERTS FOR LIFTING AND HANDLING OF PRECAST CONCRETE ELEMENTS – STATE OF THE ART

BEMESSUNG VON TRANSPORTANKERN FÜR BETONFERTIGTEILE – AKTUELLER STAND

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SUMMARY

Inserts and insert systems for rapid and safe lifting and handling operations of precast concrete components have proven as crucial for their fast and economic transport and erection. However, actually no uniform European Standards exist for the prequalification and design of these vital products. However, there is the German VDI/BV-BS 6205 [1] covering prequalification and design of lifting insert systems and serving as base for the state of the art report CEN/TR 15728 [2] and the future EN 13155 [3] dealing with prequalification procedures. This contribution summarizes the contents of and connections between the above mentioned provisions and describes the steps made in the direction of harmonization giving the users of lifting inserts the opportunity to compare their characteristics and fields of application on a common base.

ZUSAMMENFASSUNG

Transportanker und Transportankersysteme für das rasche und sichere Versetzen von Betonfertigteilen haben sich als nahezu unverzichtbar für deren raschen und sicheren Transport und Einbau erwiesen. Allerdings besteht bis heute kein einheitlicher europäischer Ansatz für die Qualifizierung und Bemessung diese überaus wichtigen Produkte. Es gibt allerdings die deutsche Richtlinie VDI/BV-BS 6205 [1], die Qualifizierungs- und Bemessungsregeln enthält und als Grundlage für den Sachstandsbericht CEN/TR 15728 [2] sowie die zukünftige Produktnorm EN 13155 [3] dient. EN 13155 beschränkt sich jedoch ausschließlich auf die Produktqualifizierung. Dieser Beitrag fasst die Inhalte und Verbindungen zwischen den vorgenannten Dokumenten zusammen und beschreibt die Schritte in Richtung der Harmonisierung, um den Verwendern so

die Möglichkeit des Vergleichs der Leistungsfähigkeit von Transportankern und Transportankersystemen auf einer gemeinsamen Grundlage zu ermöglichen.

KEYWORDS: Lifting inserts, precast concrete element, lifting, handling

1. INTRODUCTION

The fast, economic and high-quality construction of concrete structures with precast concrete elements requires inserts and insert systems for rapid and safe lifting and handling during transport and erection. The regulations covering the use and the design of these fasteners are actually still primarily based on experience as well as the results from product specific and application oriented tests. Hence, these regulations are not uniform in Europe, although, concerning the anchorage of the inserts, in the precast components the same physical conditions are given as in concrete structures cast on site where harmonised rules exist.

Inserts for lifting and handling are installed permanently in reinforced concrete precast components. However, they are used only temporarily and are not permitted to contribute to the mechanical resistance and stability of the completed structure. Their designated use ends with the assembly of the precast concrete components.

For this reason inserts and insert systems for lifting and handling are not specified as construction products but machinery components:

In the sense of European regulations they are considered as lifting accessories, i.e. as a component of the complete load resisting chain consisting of crane, crane rope, crane hook, lifting key and cast-in lifting insert or lifting insert system consisting of lifting key and lifting insert (Fig. 1). Thus they are covered by the European Machinery Directive 2006/42/EC [4] and addressed by the Construction Product Regulation [5]. They will be covered in the next future by the revised standard EN 13155 ‘Crane — Safety — Non-fixed load lifting attachments’ which was developed under the premises of the European Machinery Directive 2006/42/EC. The consequences for the design of the anchorage of the inserts resulting from this classification are considered in greater detail in the following.

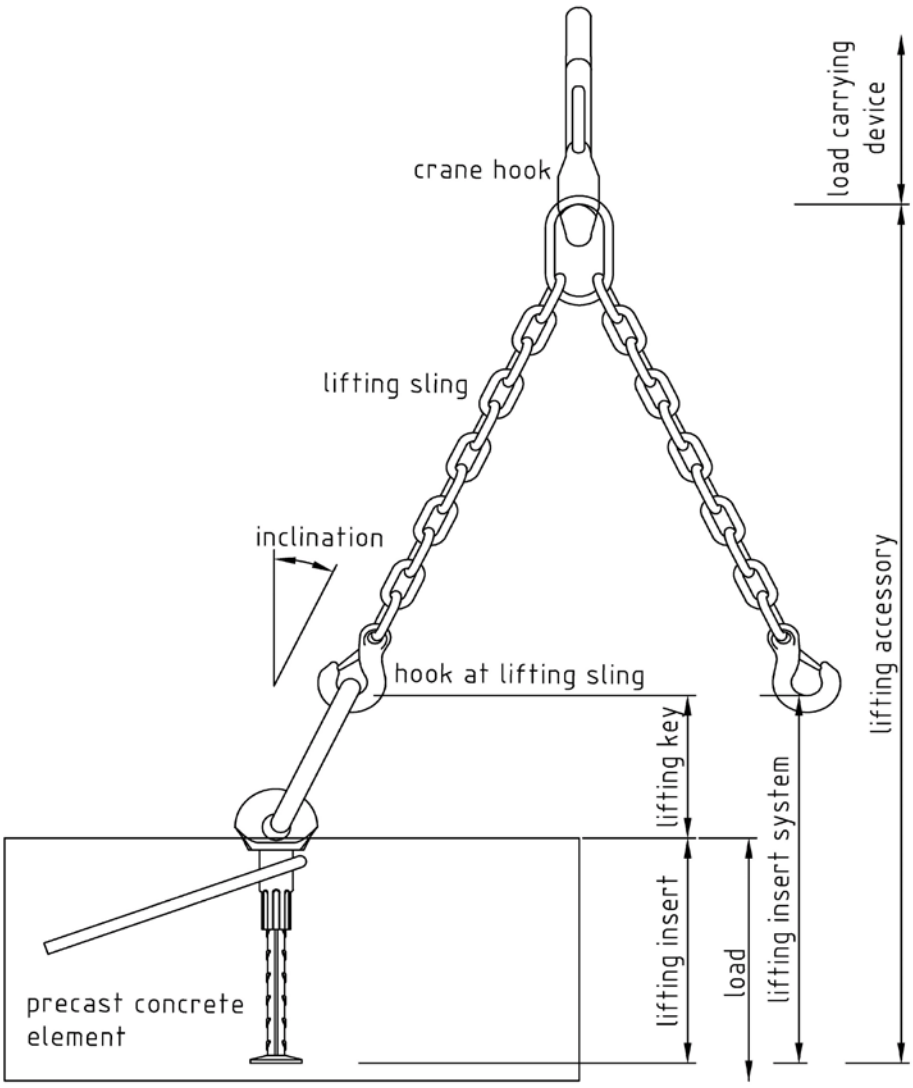

Fig. 1: Example of lifting insert system and definitions

2. LIFTING INSERT SYSTEMS AND THEIR USE

Health and safety requirements of the Machinery Directive have to be observed during all lifting operations. Therefore the precast industry predominantly uses lifting inserts which belong to a serially produced lifting insert system consisting of a lifting insert and the corresponding lifting key (Fig. 2). The lifting insert is cast in the concrete component and used only for the transport and assembling process of the precast element on site. After its use it remains in the concrete precast element without further use. The corresponding lifting key which is normally only compatible to a special lifting insert produced by the same manufacturer is repeatedly used for further lifting and handling operations of other precast elements where the same type of lifting insert is installed.

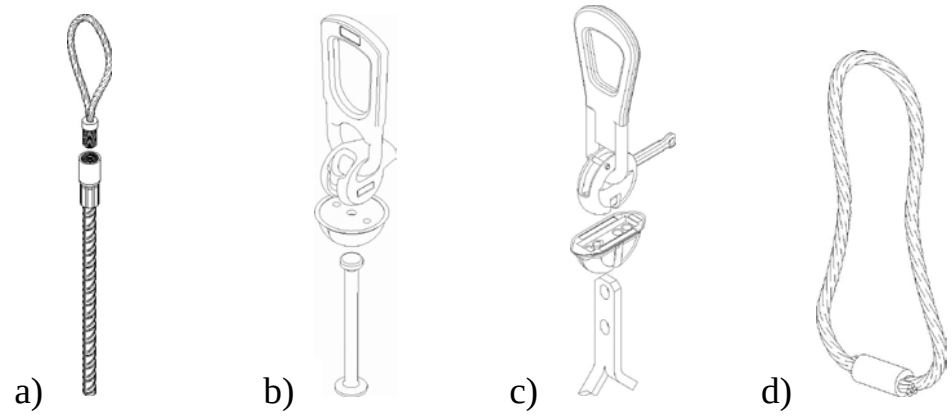

Fig. 2: Examples of lifting inserts and corresponding lifting keys (a) to c)) and d) lifting insert where the lifting accessory is directly applied

Sometimes lifting keys of one manufacturer can be screwed in the thread of the lifting insert of another manufacturer. Lifting inserts and keys are often produced with a round thread which is not standardized, so that a fit of round threads of different manufacturers normally cannot be considered as sufficiently load-bearing. Furthermore it is also possible that a lifting key has a sharp thread and both parts can be screwed together. In this case a safe load bearing connection is also not ensured. On the contrary such incompatibilities between lifting inserts and lifting keys might yield the failure of the connection during the lifting and handling operations with considerable health and economic consequences.

To avoid this foreseeable misuse it is highly desirable that lifting insert systems are modified in such a way that not properly fitting parts cannot be connected or failure occurs before the precast element is lifted. However, the best alternative is, that the connections between lifting inserts and lifting insert systems are standardized and lifting inserts and lifting keys are always compatible.

In general, a system for lifting and handling of precast elements covers a specific range of application such as e.g. lifting of planar (e.g. slabs) or bar-shaped components (e.g. columns). This restriction ensures a safe and economic lifting and handling process. The specific ranges of application for the respective type of inserts are found in the lifting and handling instructions of the manufacturers. Besides, these include the corresponding load-carrying capacities for a minimum concrete compressive strength of 15 N/mm² of the precast concrete element at the time of the first lifting operation, the minimum concrete component dimensions and if necessary shape and type of the necessary supplementary reinforcement required for the specific type of application.

3. ACTUAL REGULATIONS

3.1 MACHINERY DIRECTIVE 2006/42/EC – EN 13155

The use of lifting inserts and lifting insert systems is covered by the European Machinery Directive 2006/42/EC. It regulates only the steel parts of the insert i.e. the lifting insert exclusively as a product. Regulations for the concrete serving as anchorage material are not given. The load-carrying capacity of lifting inserts, however, is in most cases governed by concrete failure i.e. in the design the verification of concrete failure becomes decisive. Thus the properties and dimensions of the precast concrete element serving as base for the anchorage of the inserts are essential. This gap will be closed in the future by the revised EN 13155 to ensure that the essential health and safety requirement given in [5] are kept and lifting inserts can be safely used. The revised version of EN 13155 is at the moment of the creation of this contribution in the CEN Formal Vote process. This means that EN 13155 is technically completed and only editorial changes are possible. The publication of the new EN 13155 is expected in 2020.

EN 13155 will be a harmonized standard but not necessarily replace national and complementary documents. A lifting insert or lifting insert system producer remains free to apply specifications alternative to EN 13155. The voluntary nature of harmonised European standards is intended to prevent technical standards being an obstacle to the placing on the market of machinery incorporating innovative solutions.

Harmonised standards provide an indication of the state of the art at the time they were adopted. They indicate the level of safety which can be expected of a given type of product at that time. A producer who chooses to apply other technical specifications must be able to demonstrate that his alternative solution is in conformity with the essential health and safety requirements of the Machinery Directive and provide a level of safety that is at least equivalent to the requirements of the harmonised standard.

When a lifting insert producer chooses not to apply EN 13155 or to apply only parts of it, he must include in the technical file serving as base for the lifting and handling instructions the risk assessment undertaken and the steps taken to comply with the essential health and safety requirements of the Machinery Directive 2006/42. In such a case, the reference to EN 13155 should not be listed in the manufacturer’s EC Declaration of Conformity, but the Declaration may indicate which parts or clauses of EN 13155 have been applied.

In any case EN 13155 will still be a product standard. Therefore the declaration of performance of lifting inserts CE-marked based on EN 13155 will include performance data of the inserts and insert systems but give no information on the design procedure to be used.

The design standard EN 1992-4 ‘Design of fastenings for use in concrete’ covers permanent fastenings and therefore in case of the design of lifting inserts refers to the provisions of CEN/TR 15728 ‘Design and Use of Inserts for Lifting and Handling of Precast Concrete Elements’ prepared by CEN/TC 229 for the design of the anchorage of lifting inserts in concrete. Nevertheless, it is recommended to better use the VDI/BV-BS 6205 guideline ‘Lifting Inserts and Lifting Insert Systems for Precast Concrete Elements, Principles, Design, Applications’, instead. The information given in CEN/TR 15728 and VDI/BV-BS 6205 served as base for the development of the EN 13155 Sections covering lifting inserts and lifting insert systems and agree with EN 13155. A revised VDI/BV-BS 6205 which takes into account the provisions of EN 13155 is expected to be published 2020.

Background to CEN/TR 15728 and VDI/BV-BS 6205 is given in the following.

3.2 CEN/TR 15728

CEN/TC 229 ‘Precast Concrete Products’ wanted to create a base for the uniform and safe use and design of lifting inserts on European level with the first version of the Technical Report CEN/TR 15728 ‘Designs and Use of Inserts for Lifting and Handling’, published in 2008. This was an urgent need, because for comparable lifting inserts under comparable application conditions depending on the country and manufacturer partly contradictory test, assessment and design recommendations were given. In the meantime, the version of 2008 was basically reworked and all still existing inconsistencies were removed. The revised version was published in 2016.

CEN/TR 15728 applies exclusively to lifting inserts which serve the lifting and handling operations of precast concrete components produced of normal concrete. The production of the concrete components must be subject to a quality assurance process which includes the installation and the use of the lifting inserts.

The revised CEN/TR 15728 defines clearly and exemplarily the actual state of knowledge in the selection of lifting inserts as well as the test-supported

determination of their characteristic and admissible resistances by means of clear requirements to the planning, performance, evaluation and assessment of tests and corresponding results. This is also valid for special kinds of applications such as inserts for the lifting of pipes (Fig. 3). The evaluation concept is based on EN 1990.

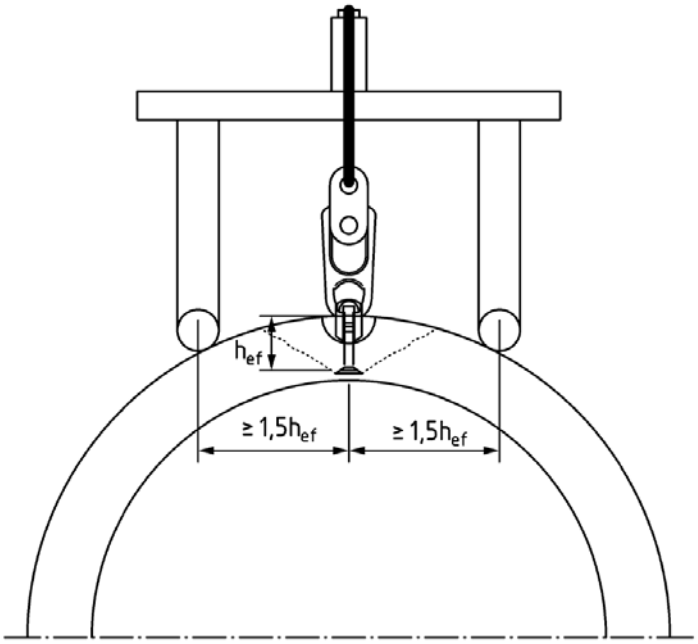

Fig. 3: Test of lifting inserts and lifting insert systems under tensile load in pipes -example

The selection of the lifting insert according to CEN/TR 15728 occurs on the basis of the geometry of the precast component to be moved. It is distinguished between the applications in flat components as for example to walls or slabs, bar-shaped components as for example columns or beams, and massive components as well as pipes.

The design of lifting inserts is based on test results or calculations, where the EN 1992-4 model serves as base. A sufficient safety level during lifting and handling of precast concrete products with lifting inserts is ensured by stating partial and global safety factors for different failure modes from different National Provisions and the global safety factors as required by the Machinery Directive.

CEN/TR 15728 is a state of art report in the area of structural engineering. For reasons of the unclear legal situation – a document provided under the umbrella

of the Construction Products Regulation covering a product covered by the Machinery Directive - CEN/TR 15728 excludes its use as an interpretation paper to the European Machinery Directive in 2006/42/EC.

3.3 VDI/BV-BS 6205

VDI/BV-BS 6205 guideline ‘Lifting Inserts and Lifting Insert Systems for Precast Concrete Elements’ is more detailed than CEN/TR 15728. The focus is on serially produced lifting insert systems for lifting and handling operations of structural precast components since this type of inserts is nearly exclusively used by the German precast industry. In the very special case where a precast factory produces its own special lifting inserts it is highly recommended to analogously use and follow the VDI/BV-BS 6205 rules to create a comparable safety level.

The actual VDI/BV-BS 6205 guideline consists of Part 1: General Principles, Part 2: Manufacturing and Placing on the Market and Part 3: Design and Application. Part 1 incorporates general principles to be considered by producers, designers and users. Part 2 addresses producers and suppliers of lifting inserts and the focus of Part 3 are designers and users. The principles and requirements of Part 2 and Part 3 are supplementary to Part 1.

Currently VDI/BV-BS 6205 is under revision to ascertain that it is in full agreement with the upcoming revision of EN 13155 and can be further used without conflict with the Machinery Directive 2006/42 EC. Since VDI/BV-BS 6205 served as base document for the revision of EN 13155 no technical changes exist. The revised version mainly aligns definitions and actions to be taken by the insert producer to cover foreseeable misuse. For reasons of practicability the revised version will consist of just one volume. The publication is planned for 2020 in parallel with the revised version of EN 13155, so that it can be used also as commentary to the corresponding lifting insert sections.

VDI/BV-BS 6205 provides design criteria and default values for the lifting insert producers, e.g. concerning the ductility of the steel to be used in production. Thus in case of appropriate use even at very deep temperatures sufficient deformation capacity exists and the precast element can be safely handled.

The determination of the resistance of lifting inserts can occur on the basis of tests, proof loading and physically based design models. Reproducible and clearly defined testing is performed application oriented whereas testing and

corresponding evaluation procedure conform substantially to the rules of CEN/TR 15728. This permits the determination of reliable resistances appropriate for the technical documents of the lifting inserts e.g. the lifting and handling instructions.

Deviating from the usual approach of the Eurocodes and EN 1992-4 the safety concept corresponds to the demands of the Machinery Directive. Hence, the verifications of the load-carrying capacity as in EN 13155 are not performed at the design level, but on the basis of the admissible load level by means of global safety factors. It shall be shown that

$$E \leq R_{adm} \tag{1}$$

with:

E load acting on a lifting insert

R_{adm} admissible load (resistance) of a lifting insert

$$R_{adm} = R_k / \gamma \tag{2}$$

with:

R_k characteristic value of the resistance of the anchorage of a lifting insert pursuant the installation and lifting instruction, depending on the selected lifting insert and its application

γ global safety factor, dependent on the failure mode, factor to cover uncertainties in action and resistance

The global safety factors given in EN 13155 or the revised VDI/BV-BS 6205 in case of steel failure of lifting inserts produced from steel ropes amount to $\gamma = 4{,}0$, for lifting inserts made from chains to $\gamma = 3{,}0$ and for lifting inserts produced from full cross sections to $\gamma = 3{,}0$. For the failure modes concrete break-out, splitting, blow-out and pull-out the global safety factor is $\gamma = 2{,}5$. If lifting inserts are installed in precast elements under plant specific and continuous inspection according to EN 13369 the global safety factor may be reduced to $\gamma = 2{,}3$. Thus the benefit of higher concrete quality due to proper workmanship and lesser environmental influence compared to concrete placement on site is taken into account.

The contents of the lifting and handling instructions which the producer of the lifting insert must make available to the user for the design and the installation of

the lifting insert as well as for the handling of the precast element are also defined. Special attention is given to the process for the exclusion of significant hazards and the avoidance of foreseeable misuse.

The information given in the lifting and handling instructions is also used by designers and precast plant staff for the verification of the lifting insert resistance. Although lifting inserts are subjected only to transient actions, it is vital that they do not unfavorably influence the serviceability of the precast element during its service life, e.g., due to corrosion. For the verification of the load-carrying capacity VDI/BV-BS 6205 provides instructions with respect to the static system to be selected for the distribution of the load to the single lifting inserts anchored in a precast component. The loads acting on the inserts are to be determined according to the different lifting and handling conditions. Effects from the dead load of the precast element, form adhesion and friction during lifting from the formwork as well as dynamic actions depending on the hoist (type of crane, excavator…) and the condition of the terrain on which the precast element is transported and the governing load combinations shall be observed.

The resistance, however, can be also determined by means of proof loading at the corresponding precast component or on the basis of EN 1992-4 which is valid for the determination of the resistance to structural loads. Nevertheless, it shall be mentioned that in most cases for lifting inserts the computation according to EN 1992-4 yields very conservative results. This is due to the fact that lifting insert applications are intended for transient load transfer only, very specific and usually particular measures such as addition of special supplementary reinforcement are taken to allow for lifting of the precast element at an early age.

The VDI/BV-BS 6205 guideline represents a uniform and comprehensive procedure for the design, the construction as well as the determination of the resistance via test, assessment or computation and finally use of lifting inserts. Besides, the basic health and safety requirements of the Machinery Directive were considered. In addition the revised version will observe the revised EN 13155 in detail.

4. SUMMARY

The anchorage of lifting inserts and lifting insert systems will be covered by EN 13155 in 2020, which will be commented in detail by the revised VDI/BV-BS 6205. Until then lifting inserts and lifting inserts are only

insufficiently addressed by the Machinery Directive 2006/42. This deficiency is settled by the application of CEN/TR 15728. In Germany the normative gap is closed by the VDI/BV-BS 6205 guideline. It corresponds in the essentials with the revised CEN/TR 15728 and gives additional directions and explanations for the proper use of lifting inserts and lifting insert systems.

Fig. 4 indicates the level of detail of the different provisions now and in the future.

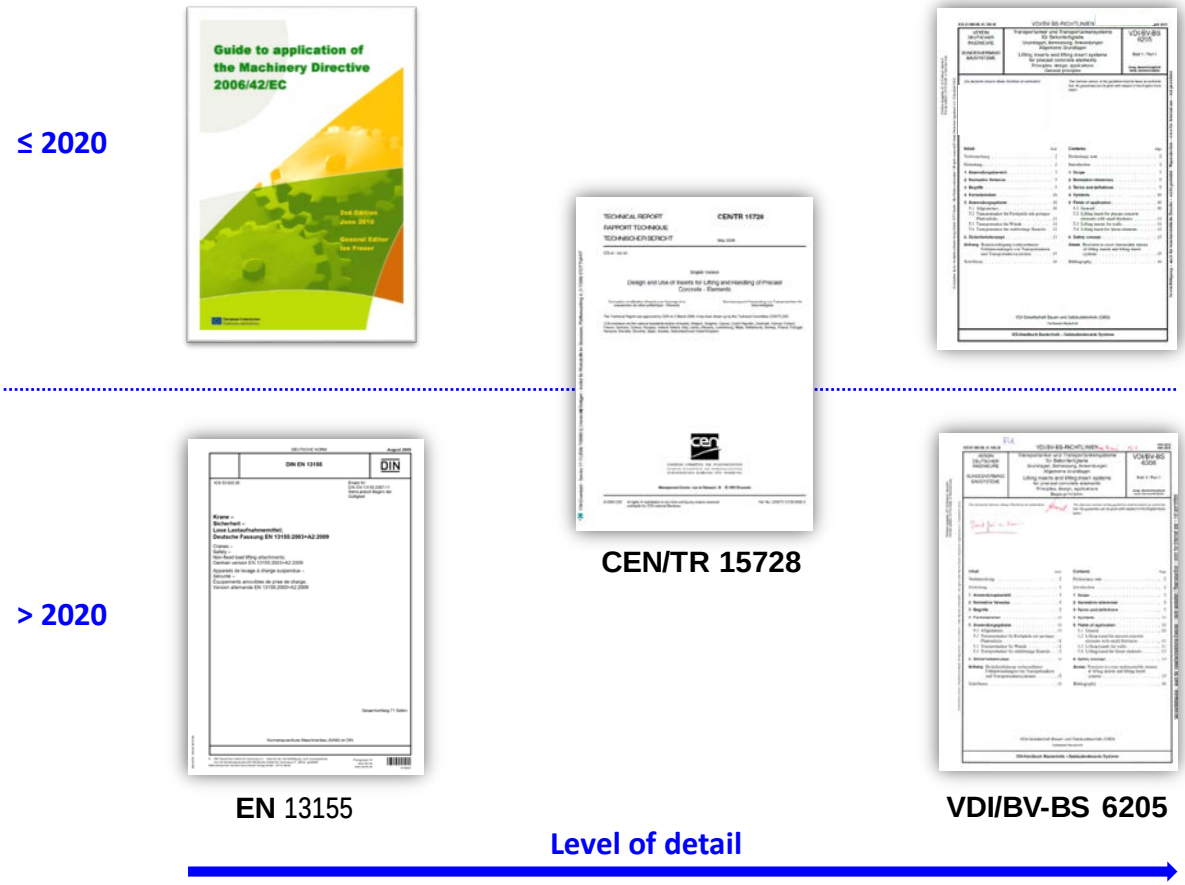

Fig. 4: Level of detail of provisions for lifting inserts and lifting insert systems

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[3] EN 13155: *Crane - Safety - Non-fixed load lifting attachments*; Formal Vote version, 2019, to be published in 2020

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[5] Construction Products Regulation, Regulation (EU) No 305/2011 of the European Parliament and of the Council of 9 March 2011 laying down harmonised conditions for the marketing of construction products and repealing Council Directive 89/106/EEC